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Barr's Buffon.

Buffon's Natural Hiſtory.

CONTAINING
A THEORY OF THE EARTH,
A GENERAL
HISTORY OF MAN,
OF THE BRUTE CREATION, AND OF
VEGETABLES, MINERALS,
&c. &c.

FROM THE FRENCH.
WITH NOTES BY THE TRANSLATOR.
IN TEN VOLUMES.
VOL. X.

London:
PRINTED FOR THE PROPRIETOR,
AND SOLD BY H. D. SYMONDS, PATERNOSTER-ROW.
1797.

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BUFFON'S

NATURAL HISTORY.

OF THE DEGENERATION OF ANIMALS.

THE deer-kind whoſe horns are a ſort of wood, and of ſolid texture, although ruminant, and internally formed like thoſe whoſe horns are hollow and porous, ſeem to form a ſeparate family, in which the elk is the trunk, and the rein-deer, ſtag, axis, fallow-deer, and roe-buck, are the leſſer and collateral branches; for there are only ſix ſpecies of animals whoſe heads are armed with branched horns which fall off and are renewed every year. Independent of this generic character, they reſemble each other ſtill more by the formation and natural habitude; we ſhould, therefore, ſooner expect mules from the ſtag or fallow-deer, joined with the rein-deer or the axis, than from an union of the ſtag with the cow.

We might be ſtill better authoriſed to regard all the different kinds of ſheep and goats, as compoſing but one family, ſince they produce together mules, which immediately, and in the firſt generation, aſcend to the ſpecies of the ſheep. We might even add to this numerous family of ſheep and goats, thoſe of the gazelles and bubalus, which are not leſs in number. The muflon, the wild goat, the chamois, the antelope, the bubalus, the condoma, &c. ſeem to be the principal trunks of this genus, which contains more than thirty different ſpecies, and the others only acceſſary branches which have retained the principal characters of the ſtocks from which they iſſued; but which, at the ſame time, have prodigiouſly varied by the influence of the climate, the difference of the food, and by the ſtate of ſlavery to which man has reduced moſt animals.

The dog, the wolf, the fox, the jackal, and the iſatis, form another genus, the different ſpecies of which reſemble each other ſo ſtrongly, eſpecially in their internal conformation, and the organs of generation, that it is difficult to conceive why they do not intermix. From the experiments I made to form an union of the dog with the wolf and fox, the repugnance to copulate ſeemed to proceed from the wolf and fox rather than from the dog, that is from the wild animal and not from the tame, for thoſe bitches which I put to the trial would readily have permitted the wolf and fox, whereas the females of the two latter would never ſuffer the approaches of the dog. The domeſtic ſtate ſeems to render animals leſs faithful to their ſpecies: it gives them alſo a greater degree of heat and fecundity, for the bitch generally produces twice in a year, while the females of the wolf and fox litter only once; and it is to be preſumed, that thoſe dogs which have been left in deſart countries, as thoſe ſo greatly multiplied in the iſland of Juan Fernandes, and in the mountains of St. Domingo, produce only once a year, like the wolf and the fox. This circumſtance, if it was proved to be the fact, would fully eſtabliſh the unity of genus in theſe three animals, which ſo ſtrongly reſemble each other by conformation as to oblige us to attribute their repugnance to ſome external circumſtances.

The dog ſeems to be the intermediate ſpecies between the fox and the wolf. The ancients have ſtated, that the dog, in ſome countries, and under particular circumſtances, engenders with the wolf and fox. I was deſirous of verifying this aſſertion, and although I did not ſucceed in the trials I made we muſt not conclude that it is impoſſible, for my experiments were with captive animals; and it is known that in ſome ſpecies captivity alone is ſufficient to extinguiſh the deſire, and give them a repugnance to copulation, even with their own kind; but I am perſuaded, that when in a ſtate of freedom, and deprived of his own female, the dog would unite with the wolf and fox, particularly if he had become wild, loſt his domeſtic caſt, and approached the manners and natural habits of theſe animals. The fox and wolf, however, never unite, though they live in the ſame climate and country, but ſupport their ſpecies pure and unmixed; we muſt, therefore, ſuppoſe a more ancient degeneration than the records of hiſtory if they ever belonged to one ſpecies; it was for this reaſon I aſſerted that the dog was an intermediate ſpecies between the fox and wolf; and his ſpecies is alſo common, ſince it can unite with both; and if any thing could ſhew that they all three originally ſprang from the ſame ſtock, it is this common affinity between the dog, the fox, and the wolf, and which ſeems to bring their ſpecies nearer than all the conformities in their figures and organization. To reduce the fox and wolf, therefore, into one ſpecies, we muſt return to a ſtate of nature very ancient indeed; but in their actual condition, as they at preſent are, we muſt look upon the wolf and fox as the chief trunks in the genus of the five animals. The dog, the jackal, and the iſatis, are only lateral branches placed between the two firſt; the jackal participates of the dog and wolf, and the iſatis of the jackal and fox. By a great number of teſtimonies it appears that the jackal and the dog ſeem to engender readily together; and it is obſervable, from the deſcription and hiſtory of the iſatis, that it almoſt entirely reſembles the fox in its form and temperament, that they are equally found in cold countries, but that, at the ſame time, it inclines to the jackal in its diſpoſition, continual barking, clamorous voice, and the habit of always going in packs.

The ſhepherd's dog, which I have conſidered as the original ſtock of every other dog, is, at the ſame time, that which approaches neareſt in figure to the fox. He is of the ſame ſize, and, like the fox, he has erect ears, a pointed muzzle, and a ſtrait trailing tail. He alſo draws near the fox by voice, ſagacity, and inſtinct. The dog, therefore, may originally have been the iſſue of the fox, if not in a direct at leaſt in a collateral line. The dog, which Ariſtotle calls *canis-laconicus*, and which he affirms to have proceeded from an union of the fox and dog, might, poſſibly, be the ſame as the ſhepherd's dog, or, at leaſt, it has more relation to him than any other dog. We might, therefore, be inclined to imagine, that the epithet *laconicus*, left uninterpreted by Ariſtotle, was only given to this dog becauſe he was found in Laconia, a province of Greece; but if we attentively conſider the origin of this *laconic* dog, we ſhall perceive that the breed was not confined to the country of Laconia alone, but muſt have been found in every country where there are foxes; and this induces me to preſume, that the epithet *laconicus* might poſſibly have been uſed by Ariſtotle to expreſs the brevity and acuteneſs of his voice, becauſe he did not bark like other dogs, but had a ſhorter and ſhriller note, like that of the fox. Now our ſhepherd's dog is that to which we can juſtly apply this term of *laconic*, for of all dogs his voice is the ſharpeſt and moſt rarely employed. Beſides, the characters which Ariſtotle gives his laconic dog agree with thoſe of the ſhepherd's dog, and perfectly perſuades me they are the ſame.

The genus of cruel and rapacious animals is one of the moſt numerous and moſt diverſified: the lion and the tiger, being detached ſpecies, rank in the firſt line; all the others, as the panther, the ounce, the leopard, the lynx, the caracal, the jaguar, the couguar, the ocelot, the ſerval, the margai, and the cat, compoſe only one cruel family, whoſe different branches are more or leſs extended and diverſified according to the difference of climates. All theſe animals reſemble each other in natural diſpoſitions, although they are very different with reſpect to ſize and figure. They all have ſparkling eyes, ſhort muzzles, and ſharp crooked and retractile claws. They are all deſtructive, ferocious, and untameable. The cat, which is the laſt and the leaſt ſpecies, although reduced to ſlavery, continues its ferocity, and is no leſs perfidious. The wild cat has preſerved the character of the family, and is as cruel and miſchievous as any of his larger kindred. They are all alike carnivorous, and enemies to other animals. Man, with all his art and power, has not been able to annihilate them: fire, ſteel, poiſon, pits, and every method has been uſed againſt them without attaining that point. As the individuals are very prolific, and the ſpecies numerous, the efforts of man has been limited to keeping them at a diſtance, and confining them in the deſarts, from whence they never ſally without ſpreading terror, and making great depredations. A ſingle tiger iſſuing from the foreſt is ſufficient to alarm a multitude of people, and oblige them to take up arms. What then would be the conſequence if theſe ſanguinary animals came in numbers, like wolves, or jackals, to commit their depredations? Nature has given this inſtinct to timid animals, but fortunately denied it to the bold tribes, they go ſingly, and depend upon their courage and ſtrength for their ſafety and ſupport. Ariſtotle obſerved, and juſtly remarked, that of all animals furniſhed with talons not any of them are ſociable, or go together in troops. This obſervation, which was then confined to four or five ſpecies only, which alone were known in his time, is extended and verified over ten or twelve other ſpecies ſince diſcovered. Other carnivorous animals, ſuch as the wolf, the fox, the dog, the jackal, and the iſatis, whoſe claws are ſtraight, go moſtly in troops, and are all timid, and even cowardly.

By comparing in this manner every quadruped, and ranking each with its proper genus, we ſhall find, that the two hundred ſpecies we have given the hiſtory of, may be reduced to a ſmall number of families, or principal ſtems, from which it is not impoſſible all the others have derived their origin.

To place this reduction in a regular method we ſhall obſerve, that all the animals of the two continents, as well as all thoſe peculiar to the Old World, may be reduced to fifteen genera, and nine ſolitary ſpecies. Theſe genera are firſt, the whole hoofed genus, properly ſo called, which includes the horſe, the zebra, and the aſs, with all the prolific and barren mules. 2. The large cloven-hoofed with hollow horns, as the ox and the buffalo, with their varieties. 3. The ſmall cloven-hoofed animals with hollow horns, ſuch as the ſheep, the goat, the gazelle, the antelope, and every other ſpecies which participates of their nature. 4. The cloven-hoofed with ſolid horns, which are ſhed and renewed every year; this family contains the elk, the rein-deer, the ſtag, the fallow-deer, the axis, and the roe-buck. 5. The ambiguous cloven-hoofed, which is compoſed of the wild boar, and all the varieties of the hog, ſuch as that of Siam, with a hanging belly, that of Guinea, with long ears, pointed and turned backwards, and that of the Canary iſlands with thick and long tuſks, &c. 6.

The very extenſive race of digitated carnivorous animals with crooked and retractile claws, in which we muſt comprehend the panther, leopard, guepard, ounce, ſerval, and cat, with all their varieties. 7. The digitated carnivorous animals with ſtraight and fixed claws, which include the wolf, fox, jackal, iſatis, and the dog, with all their varieties. 8. The digitated carnivorous animals with fixed claws, and a pouch under their tails. This conſiſts of the hyæna, civet, zibet, badger, &c. 9. The digitated carnivorous animals with long bodies, five toes to each foot, and the great toe, or thumb, divided from the reſt; this genus is compoſed of the ferret, martin, pole-cat, weaſel, ſable, ichneumon, &c. 10. The numerous family of digitated quadrupeds which have two large inciſive teeth in each jaw, and no briſtles on their bodies; this contains the hare, rabbit, and every kind of ſquirrels, dormice, marmots, and rats. 11. The digitated quadrupeds, whoſe bodies are covered with ſpiny quills, as the porcupine and hedge-hog. 12. The digitated animals covered with ſcales, as the long and ſhort-tailed manis, or ſcaly lizards. 13. The amphibious digitated genus, which includes the beaver, otter, muſk-rats, walrus, and ſeals. 14. The four-handed genus, which comprehends the apes, baboons, monkies, makis, loris, &c. 15. The winged quadrupeds, which includes bats, &c. with all their varieties. The nine detached ſpecies are the elephant, rhinoceros, hippopotamus, giraffe, camel, lion, tiger, bear, and mole, which are all ſubject to a greater or ſmaller number of varieties.

Of thoſe fifteen genera, and nine detached ſpecies, ſeven genera and two ſpecies are common to both continents. The two ſpecies are, the bear and the mole; and the ſeven genera are, 1. The great cloven-hoofed with hollow horns, for the ox is found in America, under the form of the biſon. 2. The cloven-hoofed, with ſolid horns, for the elk exiſts in Canada, under the name of orignal; the rein-deer, under that of caribou; and ſtags, fallow-deer, and roe-bucks, are found in all the provinces of North America. 3. The digitated carnivorous animals with fixed claws; for the wolf and fox are found in the New World as well as in the Old. 4. The digitated animals with long bodies, as the weaſel, martin, and pole-cat, are met with in America as well as in Europe. 5. We find alſo in America, part of the digitated genus with two large inciſive teeth in each jaw, as the ſquirrels, marmots, rats, &c.

6. The digitated amphibious genus, as the walrus, ſeal, beaver, and otter, exiſt in the North of the New Continent. 7. The winged genus exiſt alſo in America, as the bat and vampire.

There remains, therefore, only eight genera, and five detached ſpecies, which are peculiar to the Old Continent. Theſe eight genera are, 1. The whole hoofed, properly ſo called, for neither the horſe, aſs, zebra, or mule, were met with in the New Continent. 2. The ſmall cloven-hoofed beaſts with hollow horns; for ſheep, goats, gazelles, nor antelopes exiſted in America. 3. The family of hogs; for the ſpecies of wild boar is not to be found in America; and although the pecari, and its varieties, are related to this family, yet they differ in a ſufficient number of remarkable characters to juſtify their ſeparation. 4. It is the ſame with carnivorous animals with retractile claws; we do not meet with either the panther, leopard, guepard, ounce, or ſerval, in America; and although the jaguar, couguar, ocelot, and margai, ſeem to belong to this family, there is not one of theſe ſpecies of the New World found in the Old, nor one of the Old to be met with in the New. 5. The ſame remark may be applied to the digitated quadrupeds whoſe bodies are covered with prickles; for although the coendou and the urſon approach very nigh to this genus, nevertheleſs, theſe ſpecies are very different from thoſe of the porcupine and hedge-hog. 6. The digitated carnivorous genus with fixed claws, and a pouch under the tail, for the hyæna, civets, and the badger, do not exiſt in America. 7. The four-handed genus, for neither apes, baboons, monkies, nor makis, have ever been ſeen in America. The ſapajous, ſagoins, opoſſums, &c. although quadrumanous, yet they eſſentially differ from thoſe of the Old Continent. 8. The digitated genus whoſe bodies are covered with ſcales; for none of the ſcaly lizards are found in America, and the ant-eaters to whom they may be compared, are covered with hair, and differ too much from the ſcaly lizards to be conſidered of the ſame family.

Of the nine detached ſpecies, ſeven, namely the elephant, rhinoceros, hippopotamus, giraffe, camel, lion, and tiger, are found only in the Old World; and two, viz. the bear and mole, are common to both continents.

If we, in the ſame manner, enumerate the animals which are peculiar to the New World, we ſhall find, that there are about fifteen different ſpecies which may be reduced to ten genera and four detached ſpecies. Theſe four ſpecies are the tapir, the cabiai, the lama, and the pecari; but there is only the tapir we can abſolutely term detached; for the pecari has varieties; and the pacos may be united to the lama, and the Guinea hog to the cabiai. The ten genera are, 1. Eight ſpecies of ſapajous. 2. Six ſpecies of ſagoins. 3. The opoſſums, phalangers, tarſiers, &c. 4. The jaguars, couguars, ocelots, margais, &c. 5. Three or four ſpecies of coaitis. 6. Four or five ſpecies of mouffettes. 7. The agouti genus, which comprehends the acouchi, the paca, the aperea, and the tapeti. 8. That of the armadillos which conſiſts of ſeven or eight ſpecies. 9. Two or three ſpecies of ant-eaters; and, 10thly, The ſloth, of which we are acquainted with but two ſpecies.

Now theſe ten genera, and four detached ſpecies, to which all the animals peculiar to the New World may be reduced, though they differ from thoſe of the Old Continent, nevertheleſs have ſome relations which ſeem to indicate ſome common affinity in their formation, and lead us to cauſes of degeneration more ancient than any of the reſt. We have already made the general remark that all animals of the

New World, were much ſmaller than thoſe of the Old. This great diminution in ſize, whatever may be the cauſe, is a primary kind of degeneration, which could not be made without having a great influence on the figure of the animal, and we muſt not loſe ſight of this effect in comparing them together.

The largeſt is the tapir, which can only be compared with the elephant, rhinoceros, and hippopotamus ; though he is not above the ſize of an aſs, he claims the firſt place for ſize in the New Continent, as the elephant does in the Old. Like the rhinoceros, his upper lip is muſcular and projecting ; and, like the hippopotamus, he often enters the water. In ſome reſpects he repreſents them all three, and his figure, which partakes more of the aſs than of any other animal, ſeems to be as degraded as his ſtature is diminiſhed. The horſe, the aſs, the zebra, the elephant, the rhinoceros, and the hippopotamus, had no exiſtence in America ; neither was there an animal in this New Continent which could be compared with them, either with reſpect to ſize or figure. The tapir appears to have ſome affinity to the whole of the ſpecies, but he is ſo mixed, and approaches ſo little to any one of them that it is not poſſible to attribute his origin to any particular ſpecies. And, notwithſtanding theſe trifling relations he is found to have with the rhinoceros, the hippopotamus, and the aſs, we muſt look on him not only as a peculiar ſpecies, but even as a ſingular genus.

The tapir, therefore, does not belong to any ſpecies of the Old Continent, and ſcarcely bears any characters which approximate him to thoſe animals we have juſt been comparing him. The nature of the cabiai is likewiſe averſe to our compariſon: externally he has no reſemblance with any other animal, and only approaches the Indian hog of the ſame continent, by his internal parts, and both ſpecies are abſolutely different from all thoſe of the Old Continent.

The lama and pacos appear to have more ſignificant marks of their ancient parents: the firſt with the camel, and the ſecond with the ſheep. The lama, like the camel, has a long neck and legs, ſlender head, and the upper lip divided. He reſembles the camel alſo by his gentle manners, ſervility of diſpoſition, endurance of thirſt, and aptneſs for labour. This was the firſt and moſt uſeful domeſtic animal of the Americans: they made uſe of him to carry burdens, in the ſame manner as the Arabs do the camel. Here, therefore, are ſufficient reſemblances in the nature of theſe two animals, to which we can yet add the permanent marks of labour; for though the back of the lama is not deformed by bunches like that of the camel, he, neverthelefs, has calloſities on his breaſt, occaſioned by the like habit he is uſed to of reſting on that part of his body. Notwithſtanding all theſe affinities the lama is a very diſtinct and different ſpecies from that of the camel. He is much ſmaller, not exceeding a fourth or a third part of the camel's magnitude. The ſhape of his body, and the quality and colour of his hair, are alſo very different. His temperament is ſtill more ſo, for he is a phlegmatic animal, and delights only to live on the mountains, whereas the camel is of a dry temperament, and willingly inhabits the moſt ſcorching ſands. On the whole, there are more ſpecific differences between the camel and the lama than between the camel and the giraffe. Theſe three animals have many characters in common, by which they might be united to one genus, but, at the ſame time, they differ ſo much in other reſpects that we cannot ſuppoſe them to be the iſſue of one another; they are, therefore, only neighbours and not relations. The height of the giraffe is nearly double that of the camel, and the camel double that of the lama. The two firſt belong to the Old Continent, and form ſeparate ſpecies. The lama, therefore, which is only found in the New, muſt be a diſtinct ſpecies from both.

It is not the ſame with reſpect to the pecari, for though a different ſpecies from the hog, he, nevertheleſs belongs to the ſame genus. He reſembles the hog in ſhape and almoſt every external relation, and only differs from that animal in ſome trifling characters, ſuch as the aperture on his back, ſhape of the ſtomach, inteſtines, &c. We might, therefore, be led to ſuppoſe that this animal ſprung from the ſame ſtock as the hog, and formerly he had paſſed from the Old World to the New, where, by the influence of the ſoil, he had degenerated to ſo great a degree as now to conſtitute a diſtinct ſpecies.

With regard to the pacos, though it appears to have ſome affinities with the ſheep, by the wool and habit of body, it differs ſo greatly in every other reſpect, that it cannot be looked on as a ſpecies which are either neighbours or allies. The pacos is rather a ſmall lama, and has not a ſingle mark which indicates its having paſſed from one continent to the other. Thus of the four detached ſpecies peuliar to the New World, three, namely, the tapir, the cabiai, the lama, the pacos, appear to belong originally to this continent, whereas the pecari, which forms the fourth, ſeems to be only a degenerated ſpecies of the hog, and to have formerly derived its origin from the Old Continent.

By examing and comparing, in the ſame manner, the ten genera, to which we have reduced the other animals peculiar to South America, we ſhall diſcover, not only ſingular relations in their nature but marks of their ancient origin and degeneration. The ſapajous and ſagoins bear ſo great a reſemblance to the monkies, that they are commonly included under that name. We have proved, however, that their ſpecies, and even their genera, are different. Beſides, it would be very difficult to conceive how the monkies of the Old Continent could aſſume in America a different-ſhaped viſage, a long, muſcular, and prehenſile tail, a large partition between the noſtrils, and other characters, both ſpecific and generic, by which we have diſtinguiſhed and ſeparated them from the ſapajous. But as the monkies, apes, and baboons, are only found in the Old Continent, we muſt look upon the ſapajous and ſagoins as their repreſentatives in the New, for theſe animals have nearly the ſame form, as well externally as internally, and alſo have many things in common in their natural habits and diſpoſitions. It is the ſame with reſpect to the makis, none of which are found in America, yet they ſeem to be repreſented there by the opoſſums, or four-handed animals, with pointed muzzles, which are found in great numbers in the New Continent, but exiſt not in the Old. We muſt, however, obſerve, that there is much more difference between the nature and the form of the makis, and of theſe four-handed American animals than between the monkies and the ſapajous; and that there is ſo great a diſtance between the opoſſums and the maki that we cannot form an idea that the one ever proceeded from the other, without ſuppoſing that degeneration can produce effects equal to thoſe of a new nature; for the greateſt number of theſe American four-handed animals have a pouch under the belly, ten inciſive teeth in each jaw, and a prehenſile tail; whereas the maki has a flaccid tail, no pouch under the belly, and only four inciſive teeth in the upper jaw, and ſix in the lower; therefore, though all theſe animals have hands and fingers of the ſame form, and alſo reſemble each other in the elongation of the muzzle, yet their ſpecies, and even their genera, are ſo different, that we cannot imagine them to be one and the ſame iſſue, or that ſuch great and general diſparities have ever been produced by degeneration.

On the other hand, the tigers of America, which we have indicated by the names of jaguars, couguars, ocelots, and margais, though different in ſpecies from the panther, leopard, ounce, guepard, and ſerval, of the Old Continent, are, nevertheleſs, of the ſame genera. All theſe animals greatly reſemble each other, as much externally as internally; they have alſo the ſame natural diſpoſitions, the ſame ferocity, the ſame vehement thirſt for blood, and what approximates them ſtill nearer in genus, thoſe which belong to the ſame continent differ more from each other than from thoſe of the other Continent. For inſtance, the African panther differs leſs from the Braſilian jaguar than the latter does from the couguar, though they are natives of the ſame country. The Aſiatic ſerval, and the margai of Guiana, likewiſe differ leſs from one another than from the ſpecies peculiar to their own continents. We, therefore, may juſtly ſuppoſe, that theſe animals had one common origin, and that, having formerly paſſed from one continent to the other, their actual differences have proceeded only from the long influence of their new ſituation. The mouffettes, or ſtinkards, of America, and the polecat of Europe, ſeem to be of the ſame genus. In general, when a genus is common to both continents the ſpecies which compoſe it are more numerous in the Old than in the New; but in this inſtance it is quite the contrary, for there are four or five kinds of polecats in America, while we have only one, the nature of which is inferior to that of all the reſt; ſo that the New World, in its turn, ſeems to have repreſentatives in the Old; and if we judged only from the fact we might think theſe animals had taken the oppoſite road, and paſſed from America to Europe. It is the ſame with reſpect to ſome other ſpecies. The roe-bucks and the fallow-deer, as well as the ſtinkards, are more numerous, larger, and ſtronger in the New Continent than in the Old; we might, therefore, imagine them to be originally natives of America; but as we cannot doubt but that every animal was created in the Old Continent, we muſt, conſequently, admit of their migration from the Old to the New World, and at the ſame time ſuppoſe, that inſtead of having degenerated, like other animals, they have improved their original nature by the influence of the ſoil and climate.

The ant-eaters, which are ſingular animals, and of which there are three or four ſpecies in the New World, ſeem alſo to have their repreſentatives in the Old. The ſcaly lizards reſemble them in the peculiar character of having no teeth, and of being obliged to put out their tongues, and feed upon ants; but if we would ſuppoſe them to have one common origin, it is ſtrange, that inſtead of ſcales, with which they are covered in Aſia, they are clothed with hair in America.

With reſpect to the agoutis, pacos, and other animals of the ſeventh genus peculiar to the New Continent, we can only compare them with the hare and rabbit, from which, however, they all differ in ſpecies. What renders their being of a common origin doubtful is, the hare being diſperſed almoſt over every climate of the Old Continent, without having undergone any other alteration than in the colour of its hair. We cannot, with any foundation, therefore, imagine that the climate of America has ſo far changed the nature of our hares to ſo great a degree as to make them tapetis or apereas, which have no tail; or agoutis with pointed muzzles, and ſhort round ears; or pacos, with a large head, ſhort ears, and a coarſe hair marked with white ſtripes.

On the whole, the coaitis, the armadillos, and the ſloths, are ſo different, not only in ſpecies, but alſo in genus, from every animal of the Old World, that we cannot compare them with any one; it is alſo impoſſible to refer them to any common origin, or attribute to the effects of degeneration the prodigious differences found in their nature from that of every other animal.

Thus, of ten genera, and four detached ſpecies, to which we have endeavoured to reduce all the animals peculiar to the New World, there are only two, the genus of the jaguars, ocelots, &c. and the ſpecies of the pecari, with their varieties, which can with any foundation be connected with the animals of the Old Continent. The jaguars and ocelots may be regarded as a ſpecies of the leopard or panther, and the pecari as a ſpecies of hog. After theſe are five genera and one detached ſpecies, namely, the ſpecies of the lama and the genera of ſapajous, ſagoins, ſtinkards, agoutis, and ant-eaters, which may be compared, tho' in a very wide and equivocal manner, with the camel, monkey, polecat, hare, and ſcaly-lizards. There then remain four genera and two detached ſpecies, namely, the opoſſums, the coatis, the armadillos, the ſloths, the tapir, and the cabiai, which can neither be referred nor compared to any genera or ſpecies of the Old Continent. This ſufficiently proves that the origin of theſe animals, peculiar to the New World, cannot be alone attributed to degeneration. However great and powerful the effects of degeneration may be ſuppoſed, we cannot, with any appearance of reaſon, perſuade ourſelves that theſe animals were originally the ſame as thoſe of the Old Continent. It is more reaſonable to imagine that the two continents were formerly joined, and that thoſe ſpecies which inhabited the New World, becauſe they found the climate and ſoil moſt ſuitable to their nature, were ſeparated from the reſt by the irruption of the ſea when it divided Aſia from America. This is a natural cauſe, and ſimilar cauſes might be conceived which would produce the ſame effect; for example, if the ſea ſhould make an irruption from the eaſtern to the weſtern ſide of Aſia, and thus ſeparate the ſouthern parts of Africa and Aſia from the reſt of the Continent, all the animals peculiar to the ſouthern countries, ſuch as the elephant, the rhinoceros, the giraffe, the zebra, the orang-outang, &c. would be, relatively to the others, the ſame as thoſe of South America actually are; they would be entirely ſeparated from the animals of the temperate countries, and could not be referred to an origin common to any of the ſpecies or genera which inhabit theſe countries, on the ſole foundation that ſome imperfect reſemblances, or diſtant relations, might be obſerved between them.

We muſt, therefore, to find out the origin of theſe animals, turn back to the time when the two continents were not ſeparated, and refer to the firſt changes which happened on the ſurface of the globe. We muſt, at the ſame time, place before our view the two hundred ſpecies of quadrupeds as conſtituting thirty-eight families; and although this is not the ſtate of Nature, ſuch as it is come down to us, but, on the contrary, a much more ancient ſtate, which we can only attain by inductions and relations nearly as fugitive as time, which ſeems to have effaced their traces, we have endeavoured, by facts and monuments ſtill exiſting, to return to thoſe firſt ages of Nature, and to exhibit thoſe epochas which appear to be moſt clearly indicated.

NATURE AND PROPERTIES OF MINERALS, VEGETABLES, &c.

LIGHT, HEAT, AND FIRE.

ALL the powers of Nature with which we are acquainted, may be reduced to two primitive forces; the one which cauſes weight, and that which produces heat. To them impulſion is ſubordinate; it depends on the firſt for its particular, and on the latter for its general effects. As impulſion cannot exerciſe itſelf but by the means of a ſpring, and the ſpring only acts by virtue of the force which approaches the remote parts, it is clear, that to perform its power it has need of the concurrence of attraction: for if matters ceaſed to attract, if bodies loſt their coherence, every ſpring would be deſtroyed, every motion intercepted, and every impulſion void; ſince motion cannot tranſmit itſelf from one body to another but by elaſticity ; it is demonſtrable, that one body abſolutely hard and inflexible, would be almoſt immoveable, and entirely incapable of receiving the action of another. Attraction being general and permanent, impulſion, which in moſt bodies is neither conſtant nor fixed, depends on it as a particular effect ; for, if all impulſion was deſtroyed, attraction would ſtill equally ſubſiſt and act ; it is, therefore, this eſſential difference which makes impulſion ſubordinate to attraction in all inanimate and purely paſſive matter.

But this impulſion depends ſtill more immediately, and generally, on the power which produces heat ; for it is principally by the means of heat, that impulſion penetrates organized bodies ; it is by heat that they are formed, grow, and develope. We may refer to attraction alone all the effects of inanimate matter ; and to this power of attraction, joined to that of heat, every phenomena of live matter. By live matter I underſtand not only every thing that lives, or vegetates, but alſo every living organic molecule, diſperſed in the waſte or remains of organized bodies. In it I comprehend light, heat, fire, and all matter which appears to be active in itſelf. Now this live matter always tends from the centre to the circumference, whereas brute or inanimate matter tends from the circumference to the centre. It is an expanſive power which animates the live matter, and it is an attractive force to which the inanimate matter is obedient. Although the directions of theſe two powers are diametrically oppoſite, they balance themſelves without ever being deſtroyed, and from their combination being alike active, all the phenomena of the univerſe reſults.

But it may be ſaid, by reducing all the powers of Nature to attraction and expanſion, without giving the cauſe of either, and by rendering impulſion, (which is the only force whoſe cauſe is known and demonſtrated to our ſenſes) ſubordinate to both, do you not abandon a clear idea, and ſubſtitute two obſcure hypotheſes in its place? To this I anſwer, that as we know nothing except by compariſon, we ſhall never have an idea of what a general effect will produce, becauſe ſuch an effect would belong to every thing, we ſhould be unable to compare it to any, and conſequently there is no hope of ever knowing the cauſe or reaſon why all matter attracts, although we are ſenſible ſuch is the fact. If, on the contrary, the effect was particular, like that of the attraction of the loadſtone and ſteel, we might expect to diſcover the cauſe, becauſe it might be compared to other particular effects. To aſk why matter is extended, heavy, and impenetrable, are ill-conceived propoſitions, and merit not an anſwer; it is the ſame with reſpect to every particular property, when it is eſſential to the ſubject, and we might as well be interrogated why red is red?

It is ſufficient that the forces of attraction and expanſion are two general, real, and fixed effects, for us to receive them for cauſes of particular ones; and impulſion is one of theſe effects, which we muſt not look upon as a general cauſe, known and demonſtrated by our ſenſes, ſince we have proved that this force of impulſion cannot exiſt nor act, but by the means of attraction, which does not fall upon our ſenſes. Nothing is more evident, nay, certain, than the communication of motion by impulſion; it is ſufficient for one body to ſtrike another to produce this effect. But even in this ſenſe, is not the cauſe of attraction moſt evident, and that motion, in all caſes, belongs more to attraction than impulſion?

The firſt reduction being made, it might be perhaps poſſible to adduce a ſecond, and to bring back the power even of expanſion to that of attraction,

traction, inſomuch that all the forces of matter would depend ſolely on a primitive one. Now cannot we conceive that this attraction changes into repulſion every time that bodies approach near enough to rub together, or ſtrike one againſt the other? Impenetrability, which we muſt not regard as a force, but as an eſſential reſiſtance to matter, not permitting two bodies to occupy the ſame place, what muſt happen when two molecules, which attract the more powerfully as they approach nearer, ſuddenly ſtrike againſt each other? Does not then this invincible reſiſtance of impenetrability, become an active force, which, in the contact, drives the bodies with ſo much velocity, as they had acquired at the moment they touched? And from hence the expanſive will not be a particular force oppoſed to the attractive one, but an effect derived therefrom. I own, that we muſt ſuppoſe a perfect ſpring in every molecule of matter, to have a clear conception how this change of attraction into repulſion is performed. But even this is ſufficiently indicated by facts; the more matter is attenuated, the more it takes a ſpring. Earth and water, which are the moſt groſs aggregates, have a leſs ſpring than air; and fire, which is the moſt ſubtle of all the elements, is alſo that which has the moſt expanſive force. The ſmalleſt molecules of matter, the ſmalleſt atoms which we know are thoſe of light, and we are ſenſible of their being perfectly elaſtic, ſince the angle under which the light is reflected, is always equal to that under which it comes. We can therefore infer, that all the conſtitutive parts of matter in general, are a perfect ſpring; and that this ſpring produces all the effects of the expanſive force, every time that bodies ſtrike by meeting in oppoſite directions.

We know of no other means of producing fire, but by ſtriking or rubbing bodies together*; ſince by ſuppoſing man without any burning glaſſes, and without actual fire, he will have no other means of producing it; for the fire produced by uniting the rays of light, or by application of fire already produced, had the ſame origin.

Expanſive force, therefore, in reality might be only the re-action of the attractive, a re-action which operates every time that the primitive molecules of matter, always attracted one by the other, happen immediately to touch; for from hence it is neceſſary, that they are repelled with as much velocity as they had acquired in a contrary direction, at the moment of contact, and when theſe molecules are abſolutely free from all coherence and only obey the motion alone produced by their attraction, this acquired velocity is immenſe in the point of contact. Heat, light, and fire, which are the greateſt effects of expanſive force, will be produced every time that bodies ſhall be artificially or naturally divided into very minute parts, and ſhall meet in oppoſite directions; and the heat will be ſo much the more ſenſible, the light more bright, the fire more violent, as the molecules are precipitated one againſt the other with more velocity by their force of mutual attraction.

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* The fire, which ariſes from the fermentation of herbs heaped together, and which manifeſts itſelf in effervefcences, are not exceptions that can be oppoſed to me, ſince this production of fire depends, like all the reſt, from the action of the ſhock of the parts of matter one againſt the other.

From the above it muſt be concluded, that all matter may become light, heat, and fire; and that this matter of fire and light is not a ſubſtance different from all others but preſerves its eſſential qualities, and even moſt of the attributes of common matter, is evidently proved by, firſt, Light, though compoſed of particles almoſt infinitely minute, is, nevertheleſs, ſtill diviſible, ſince with the priſm we ſeparate the rays, or different coloured atoms one from another. Secondly, light, though in appearance endowed with a quite oppoſite quality to that of weight, that is, with a volatility which we might think eſſential, is, nevertheleſs, heavy like all matter, ſince it bends every time it paſſes near other bodies, and finds itſelf inclined to their ſphere of attraction. It is very heavy, relative to its volume, which is very minute, ſince the immenſe velocity with which light moves in a direct line, does not prevent it from feeling ſufficient attraction near other bodies, for its direction to incline and change in a very ſenſible manner to our eyes. Thirdly, the ſubſtance of light is not more ſimple than all other matter, ſince it is compoſed of parts of unequal weight; the red rays are much heavier than the blue; and between theſe two extremes there are an infinity of intermediate rays, which approach more or leſs the weight of the red, or the lightneſs of the blue, according to their ſhades. All theſe conſequences are neceſſarily derived from the phenomena of the inflection of light, and of its refraction, which, in reality, is only an inflexion which operates when light paſſes acroſs tranſparent bodies. Fourthly, it may be demonſtrated, that light is maſſive, and that it acts, in ſome caſes, as all other bodies act; for, independent of its ordinary effect, which is to ſhine before our eyes, and of its own action, always accompanied with eclat, and often with heat, it acts by its maſs when it is condenſed by uniting, and it acts to the point of putting in motion heavy bodies placed in the focus of a good burning glaſs: it turns a needle on a pivot placed in its focus: it diſplaces leaves of gold or ſilver before it melts or even ſenſibly heats them. This action, produced by its maſs, precedes that of heat: it operates between the condenſed light and the leaves of metal in the ſame manner as it operates between two other bodies which become contiguous, and, conſequently, has ſtill this property in common with all other matter. Fifthly, Light is a mixture, like common matter, not only of more groſs and minute parts, more or leſs heavy or moveable, but alſo differently ſhaped. Whoever has obſerved the phenomena which Newton calls *the acceſs of eaſy reflection*, and of *eaſy tranſmiſſion of light*; and on the effects of double refraction of rock and Iceland chryſtal, muſt have perceived that the atoms of light have many ſides, many different ſurfaces, which, according as they preſent themſelves, conſtantly produce different effects.

Here, then, is ſufficient to demonſtrate that light is neither particular nor different from common matter; that its eſſence, and its eſſential properties, are the ſame ; and that it differs only from having undergone, in the point of contact, the repulſion from whence its volatility proceeds ; and in the ſame manner as the effect of the force of attraction extends, always decreaſing as the ſpace augments, the effects of repulſion extends and decreaſes the more, but in an inverted order, inſomuch that we can apply to the expanſive force all that is known of the attractive. Theſe are two inſtruments of the ſame nature, or rather the ſame inſtrument, only managed in two oppoſite directions.

All matter will become light, for if all coherence was deſtroyed it would be divided into molecules ſufficiently minute, and theſe molecules, being at liberty, will be determined by their mutual attraction to ruſh one againſt the other. In the moment of the ſhock the repulſive force will be exerciſed, the molecules will fly in all directions with an almoſt infinite volatility, which, neverthele*ſ*s, is not equal to their velocity acquired in the moment of contact, for the law of attraction being augmented as the ſpace diminiſhes, it is evident, that at the contact the ſpace is always proportionable till the ſquare of the diſtance becomes nil, and, conſequently, the velocity acquired by virtue of the attraction muſt at this point become almoſt infinite: this velocity muſt be infinite if the contact was immediate, and, conſequently, the diſtance between the two bodies void; but there is nothing in Nature entirely nil, and nothing truly infinite; and all that I have obſerved of the *infinite* minuteneſs of the atoms which conſtitute light, of their *perfect* ſpring, and of the *nil* diſtance in the moment of contact, muſt be underſtood only with reſtriction. If this metaphyſical truth were doubted, a phyſical demonſtration may be given. It is pretty generally known that light employs ſeven minutes and a half to come from the ſun to the earth; ſuppoſing, therefore, the ſun at thirty-ſix millions of miles, light darts thro' this enormous diſtance in that ſhort ſpace, that is (ſuppoſing its motion uniform), eighty thouſand miles in one ſecond. But this velocity, although prodigious, is yet far from being infinite, ſince it is determinable by numbers. It will even ceaſe to appear ſo prodigious when we reflect on the celerity of the motion of the comets to their perihelia, or even that of the planets, and by computing that we ſhall find the velocity of thoſe immenſe maſſes may pretty nearly be compared with that of the atoms of light.

So, likewiſe, as all matter can be converted into light by the diviſion and expulſion of its parts, when they feel a ſhock one againſt another, we ſhall find that all the elements are convertible; and if it has been doubted whether light, which appears to be the moſt ſimple element, may be converted into a ſolid ſubſtance, it is becauſe we have not paid ſufficient attention to every phenomena, and were prejudiced, that being eſſentially volatile it cannot ever become fixed. But it is plain that the fixity and volatility depends on the ſame attractive force in the firſt caſe, and becomes repulſive in the ſecond; and from thence we are led to think that this change of matter into light, and from light into matter, is one of the moſt frequent operations of Nature.

Having ſhewn that impulſion depends on attraction; that the expanſive force, like the attractive, becomes negative; that light, heat, and fire, are only modes of the common exiſting matter; in one word, that there exiſts but one ſole force, and one ſole matter, ever ready to attract or repel, according to circumſtances; let us ſee how, with this ſingle ſpring, and this ſingle ſubject, Nature can vary her works, *ad infinitum.* In the point of general view, light, heat, and fire, only make one object, but in a particular point of view they are three diſtinct objects, which, although reſembling in a great number of properties, nevertheleſs differ by a few others, ſufficiently eſſential for us to conſider them as three different things.

Light, and elementary fire, it is ſaid, only compoſe one and the ſame thing. This may be, but as we have not yet a clear idea of elementary fire we ſhall deſiſt from pronouncing on this firſt point. Light and fire, ſuch as we are acquainted with, are two diſtinct ſubſtances, differently compoſed. Fire is, in fact, very often luminous, but it ſometimes alſo exiſts without any appearance of light. Fire, whether luminous or obſcure, never exiſts without a great heat, whereas light often burns with a noiſe without the leaſt ſenſible heat. Light appears to be the work of Nature, while fire is only the produce of the induſtry of man. Light ſubſiſts of itſelf, and is found diffuſed in the immenſe ſpace of the whole univerſe. Fire cannot ſubſiſt without food, and is only found in ſome parts of this ſpace where man preſerves it, and in ſome parts of the profundity of the earth, where it is alſo ſupported by ſuitable food. Light, when condenſed and united by the art of man, may produce fire, but it is only as much as it lets fall on combuſtible matters. Light is therefore no more, and in this ſingle inſtance, only the principle of fire, and not the fire itſelf: even this principle is not immediate, for it ſuppoſes the intermediate one of heat, and which appears to appertain more than light to the eſſence of fire. Now heat exiſts as often without light as light exiſts without heat: theſe two principles, therefore, might appear not to bind them neceſſarily together; their effects are not cotemporary, ſince in certain circumſtances we feel heat long before light appears, and in others we ſee light long before we feel any heat. From hence is not heat a mode of being, a modification of matter, which, in fact, differs leſs than all the reſt from that of light, but which can be conſidered apart, and ſtill more eaſily conceived? It is, nevertheleſs, certain, that much fewer diſcoveries have been made on the nature of heat than on that of light; whether man better catches what he ſees than what he feels; whether light preſents itſelf generally as a diſtinct and different ſubſtance from all the reſt, has appeared worthy of a particular conſideration; whereas heat, the effect of which is the moſt obſcure, and preſents itſelf as a leſs detached and leſs ſimple object, has not been regarded as a diſtinct ſubſtance but as an attribute of light and fire.

The firſt thing worthy of remark, is, that the ſeat of heat is quite different from that of light; the latter occupies and runs through the void ſpace of the univerſe, heat, on the contrary, is diffuſed in all ſolid matter. The globe of the earth, and all matters of which it is compoſed, have a conſiderable degree of heat. Water has its degree of heat which it does not loſe but by loſing its fluidity. The air has alſo heat, which we call its temperature, and which varies much, but is never entirely loſt, ſince its ſpring ſubſiſts even in the greateſt cold. Fire has alſo its different degrees of heat, which appear to depend leſs on its own nature, than on that of the aliments which feed it. Thus all known matter poſſeſſes warmth; and, from hence, heat is a much more general affection than that of light.

Heat penetrates every body without exception which is expoſed to it, while light paſſes through tranſparent bodies alone, and is ſtopped and in part repelled, by every opaque one. Heat, therefore, acts in a more general and palpable manner than light, and although the molecules of heat be exceſſively minute, ſince they penetrate the moſt compact bodies, it ſeems, however, demonſtrable, that they are more groſs than thoſe of light; for we make heat with light, by collecting it in a great quantity. Beſides, heat acting on the ſenſe of feeling, it is neceſſary that its action be proportionate to the groſſneſs of this ſenſe; as the delicacy of the organs of ſight appears to be to the extreme fineneſs of the parts of light; theſe parts move with the greateſt velocity, and act in the inſtant to immenſe diſtances, whereas thoſe of heat have but a ſlow progreſſive motion, which only extends to ſmall intervals of the bodies they may emanate.

The principle of all heat ſeems to be the attrition of bodies; all friction, that is, all motion, between ſolid matters produces heat; and if the ſame effect does not happen to fluids, it is becauſe their parts do not touch cloſe enough to rub one againſt the other; and that, having little adherence between them, their reſiſtance to the ſhock of other bodies is too weak for the heat to be produced to a ſenſible degree; but we often ſee light produced by an attrition of a fluid, without feeling any heat. All bodies heat as ſoon as they meet in a contrary direction; heat is, therefore, produced by the motion of all palpable matter. The production of light is alſo made by motion, but in a contrary direction, for that ſuppoſes the diviſion of matters into very minute parts: and as this operation of Nature is the ſame with reſpect to both, we muſt conclude, that the atoms of light are ſolid of themſelves, and are hot at the moment of their birth. But we cannot alike aſcertain, that they preſerve their heat in the ſame degree as their light, nor that they ceaſe from being hot before they ceaſe from being luminous. Familiar experiments indicate, that the heat of the ſun's light augments by paſſing acroſs a plain of ice, although the quantity of ice be diminiſhed conſiderably by the reflection which is made on its external ſurface, and that even the matter of glaſs retains a certain quantity. Other experiments more deeply enquired into, ſeem to prove, that light augments heat in proportion as it traverſes a greater extent of our atmoſphere.

It is well known, that heat grows leſs, or cold becomes greater, the higher we aſcend on the mountains. The heat which proceeds from the terreſtrial globe, muſt, of courſe, be ſenſibly leſs on thoſe advanced points, than it is on the plains; but this cauſe is not proportionable to the effect; the action of heat, which acts on the terreſtrial globe, not being able to diminiſh but by the ſquare of the diſtance, it does not appear that at the height of half a mile, which is only the three thouſandth part of the ſemi-diameter of the globe, whoſe centre muſt be taken for the focus of heat, that this difference, which in this ſuppoſition is only a unit and nine millions, can produce a diminution of heat nearly ſo conſiderable; for the thermometer lowers at that height at all times of the year to the freezing point. It is not probable, that this great difference of heat ſimply proceeds from the difference of the earth; and of that we muſt be fully convinced, if we conſider, that at the mouth of the volcanos, where the earth is hotter than in any other part on the ſurface of the globe, the air is nearly as cold as on other mountains of the ſame height.

The period for bodies cooling being proportioned to their diameter, it ſhould ſeem that a ſingle moment of time was ſufficient to cool the ſmall atoms of light, although they were very hot when they darted from the ſun, and this would be the caſe if they were detached; but as they almoſt immediately ſucceed each other, and are the more confined as they are nearer the place of their origin, the heat loſt by each atom falls on the neighbouring ones; and this reciprocal communication ſupports the general heat of light a longer time, and as they proceed in a conſtant direction; even in diverging rays, as their diſtance from each other increaſes according to the ſpace they run over, and as the heat which flies from each atom, as a center, diminiſhes alſo in the ſame ratio, it follows, that the light of the ſolar rays, decreaſing in an inverted ratio from the ſquare of the diſtance, that of their heat decreaſes in an inverted ratio of the ſquare of this ſame diſtance.

Taking, therefore, the ſemi-diameter of the ſun for a unit, and ſuppoſing the action of light to be as 1000, to the diſtance of a ſemi-diameter of the ſurface of this planet, in coming to us, who are thirty-ſix millions of miles diſtant; the action of light will be more than fifty thouſand times weaker than when it quitted the ſun; and the heat of each atom of light, being alſo ſuppoſed a thouſand at quitting the ſun, will be more than 20500 millions weaker than when it darted from that planet.

If even this diminution of the heat of light ſhould not be admitted by reaſon of the ſquared ſquare of the diſtance to the ſun, it will ſtill be evident that heat, in its propagation, diminiſhes more than light. If we excite a very ſtrong heat, by kindling a large fire, we ſhall only feel it at a moderate diſtance, but we ſhall ſee the light at a very great one. If we bring our hands by degrees nearer and nearer a body exceſſively hot, we ſhall perceive that the heat increaſes much more in proportion than as the ſpace diminiſhes; for we may warm ourſelves with pleaſure at a diſtance which differs only by a few inches from that at which we ſhould be burnt. All appears, therefore, to indicate, that heat diminiſhes in a greater ratio than light, in proportion as both are removed from the focus from which they iſſued.

This might lead us to imagine, that the atoms of light would be very cold when they came to the ſurface of our atmoſphere; but by traverſing the great extent of this tranſparent maſs, they receive a new heat by friction. The infinite velocity by which the particles of light graze thoſe of the air, muſt produce a heat ſo much the ſtronger as the friction is more multiplied: and it is, probably, for this reaſon, that the heat of the ſolar rays is found much ſtronger in the lower parts of the atmoſphere, and that the coldneſs of the air appears to augment as we are elevated. Perhaps, likewiſe, as light receives heat only by uniting, a great number of atoms of light is required to conſtitute a ſingle atom of heat, and this may be the cauſe why the feeble light of the moon, although in the atmoſphere, like that of the ſun, does not receive any ſenſible degree of heat. If, as M. Bouguer ſays, the intenſity of the light of the ſun to the ſurface of the earth is 300,000 times ſtronger than that of the moon, the latter muſt be almoſt inſenſible, even by uniting it in the focus of the moſt powerful burning glaſſes, which cannot condenſe it more than one hundred times; ſubtracting the half of which for the loſs by reflexion or refraction, there remains only a three hundredth part of intenſity to the focus of the glaſs.

Thus, we muſt not infer that light can exiſt without any heat, but only that the degrees of this heat are very different, according to different circumſtances, and always inſenſible when light is very weak. Heat, on the contrary, ſeems to exiſt habitually, and even to cauſe itſelf to be ſtrongly felt without light; for in general it is only when it becomes exceſſive, that light accompanies it. But the very eſſential difference between theſe two modifications of matter is, that heat, which penetrates all bodies, does not appear to fix in any one, whereas light incorporates and extinguiſhes in all thoſe which do not reflect, or permit it to paſs freely; heat bodies of all kinds to any degree, in a very ſhort time they will loſe the acquired heat, and return to the general temperature. If we receive light on black or white bodies, rude or poliſhed, it will eaſily be perceived, that ſome admit, and others repel it; and that inſtead of being affected in an uniform manner as they are by heat, they are only ſo relatively to their nature, colour, and poliſh. Black will abſorb more light than white, and the rough more than the ſmooth. Light once abſorbed remains fixed in the body which received it, nor quits it like heat; from whence we muſt conclude, that atoms of light may become conſtituent parts of bodies by uniting with the matter which compoſes them; whereas heat not fixing at all, ſeems to prevent the union of every part of matter, and only acts to keep them ſeparate. Neverthe1eſs, there are inſtances where heat remains fixed in bodies, and others where the light they have abſorbed reappears, and goes out like heat.

After all there appears to be two kinds of heat, the one luminous, of which the ſun is the focus; the other obſcure, of which the grand reſervoir is the terreſtrial globe. Our body, as making part of the globe, participates of this obſcure heat; and it is for this reaſon, that it is ſtill obſcure to us, becauſe we do not perceive it by any one of our ſenſes. It is with reſpect to this heat of the globe, as with its motion, we are ſubject to and participate thereof without feeling or doubting of it: from hence it happened that phyſicians at firſt carried all their views and enquiries on the heat of the ſun, without ſuſpecting that it makes but a very ſmall part of what we really feel; but having made inſtruments to diſcover the difference of the immediate heat of the rays of the ſun, they, with aſtoniſhment, found that the heat of them was ſixty-ſix times ſtronger in ſummer than in winter, notwithſtanding the ſtrongeſt heat of our ſummer differs only a ſeventh from the ſtrongeſt cold of our winter; from whence they have concluded, that, independent of the heat we receive from the ſun, there emanates another, even from this terreſtrial globe, which is much more conſiderable; inſomuch, that it is at preſent demonſtrable, that this heat, which eſcapes from the bowels of the earth, is in our climate at leaſt twenty-nine times in ſummer, and four hundred times in winter, ſtronger than the heat which comes to us from the ſun.

This ſtrong heat, which reſides in the interior part of the globe, and which, without ceaſing to emanate externally, muſt, like an element, enter into the combination of all the other elements. If the ſun is the parent of Nature, the heat of the earth muſt be the mother; they both unite to produce, ſupport, and animate organized beings, and to aſſimilate and compoſe inanimate ſubſtances. This internal heat of the globe, which tends always from the centre to the circumference, is, in my opinion, a great agent in nature. We can ſcarcely doubt but it is the principal influence of the perpendicularity of the trunks of trees, on the phenomena of electricity, on the effects of magnetiſm, &c. But as I do not pretend to make a phyſical treatiſe here, I ſhall confine myſelf to the effects of this heat on the other elements. It is alone ſufficient to maintain the rarefaction of the air to the degree that we breathe in; it is more than ſufficient to keep water in its ſtate of fluidity, for we have lowered the thermometers to the depth of 120 fathoms, and have found the temperature of the water was there nearly the ſame as at the like depth in the earth, namely, ten degrees, two thirds. We muſt not, therefore, be ſurprized, eſpecially as ſalt acts as a prevention, that the ſea in general does not freeze, that freſh water freezes but to a certain thickneſs, and that the water at bottom always remains liquid, even in the moſt intenſe froſts.

But of all the elements the earth is that on which this internal heat has produced the greateſt effects. This heat originally was doubtleſs much greater than it is at preſent; therefore we muſt refer to it, as to the firſt cauſe, all the ſublimations, precipitations, aggregations, and ſeparations, which have been, and ſtill continue to be made, in the internal part of the globe, eſpecially in the external layer which we have penetrated, and the matter of which has been removed by the convulſions of Nature, or by the hands of man. The whole maſs of the globe having been melted, or liquified, by fire, the internal is only a concrete or diſcrete glaſs, whoſe ſimple ſubſtance cannot receive any alteration by heat alone; there is, therefore, only an upper and ſuperficial layer, which, being expoſed to the action of external cauſes, united to that of the internal heat, will have undergone all the modifications, differences, and forms, in one word, of Mineral Subſtances, which their combined actions were enabled to produce.

Fire, which appears to be only a compound of heat and light, might only be a modification of the matter, though it does not eſſentially differ from either, and ſtill leſs from both taken together. Fire never exiſts without heat, but it can exiſt without light. Heat alone, deprived of all appearance of light, can produce the ſame effects as the moſt violent fire ; ſo can alſo light, when it is united. Light ſeems to carry a ſubſtance in itſelf which has no need of fuel ; but fire cannot ſubſiſt without abſorbing the air, and it becomes more violent in proportion to the quantity it abſorbs; whereas light, concentrated and received into a veſſel exhauſted of air, acts as fire in air ; and heat, confined and retained in a narrow ſpace, ſubſiſts and even augments with a very ſmall quantity of food. The moſt general difference between fire, heat, and light, appears, therefore, to conſiſt in the quantity, and perhaps quality, of their food.

Air is the firſt food of fire ; combuſtible matters are only the ſecond. It has been demonſtrated, by experiments, that a little ſpark of fire, placed in a veſſel well cloſed, in a ſhort time abſorbs a great quantity of air, and extinguiſhes as ſoon as the quantity or quality of this food becomes deficient. By other experiments it is proved, that the moſt combuſtible matters do not conſume in veſſels well cloſed, although expoſed to the action of the greateſt fire. Air is, therefore, the firſt and true food of fire, and combuſtible matters would not be able to ſupply it without the aſſiſtance and mediation of this element.

We have obſerved that heat is the cauſe of all fluidity, and we find, by comparing ſome fluids together, that more heat is requiſite to keep iron in fuſion than gold; and more to keep gold than tin; much leſs is neceſſary for wax, for water leſs than that, and ſtill leſs for ſpirits of wine, and a mere trifle is ſufficient for mercury, ſince the latter goes 187 degrees below what water can without loſing its fluidity; mercury, therefore, is the moſt fluid of all matter, air excepted. Now this ſuperior fluidity in air indicates the leaſt degree of adherence poſſible between its conſtituting parts, and ſuppoſes them of ſuch a figure as only to be touched at one point. It may be alſo imagined, that, being endowed with ſo little apparent energy and mutual attraction, they are, for that reaſon, leſs maſſive, and more light, than thoſe of every other body; but that concluſion appears unfounded, from the compariſon of mercury, the next fluid body, but of which the conſtituting parts appear to be more maſſive and heavy than thoſe of any other matter, excepting gold. The greater or leſſer fluidity, does not, therefore, indicate that the parts of the fluid are more or leſs weighty, but only that their adherence is ſo much the leſs, and their ſeparation ſo much the eaſier.

Air, therefore, of all the matters, is that which divides the eaſieſt, and is very near the nature of fire, whoſe property conſiſts in the expanſive motions of its parts; and it is from this ſimilarity that air ſo ſtrongly augments the activity of fire, to which it is the moſt powerful aſſiſtant, and the moſt intimate and neceſſary food. Even combuſtible matters will not keep it alive if deprived of air, for then the moſt intenſe fire will not burn; but a ſingle ſpark of air is ſufficient to kindle them, and in proportion as it is ſupplied with that element the fire becomes ſtrong, extended, and devouring.

Artificial phoſphorus, and gunpowder, ſeem, at firſt, to be an exception, for they have no need of the aſſiſtance of renewed air to inflame and wholly conſume them: their combuſtion may be performed in the cloſeſt veſſels, but that is becauſe thoſe matters, which are alſo the moſt combuſtible, contain the neceſſary quantity in their ſubſtance, therefore they have no need of the aſſiſtance of a foreign air.

This ſeems to indicate that the moſt eſſential difference between matters combuſtible and thoſe which are not ſo, conſiſts in the latter containing only a few or none of the light, ethereal, and oily matters ſuſceptible of an expanſive motion, or, at leaſt, if there that they are detained, inſomuch that they cannot exerciſe their volatility whenever the force of the fire is not ſtrong enough to ſurmount the force of adheſion which retains them united to the fixed parts of matter. It may be ſaid that this induction is confirmed by a number of obſervations well known to chemiſts; but what appears to be leſs ſo, and which, nevertheleſs, is a neceſſary conſequence of it, is, that all matter may become volatile when the expanſive force of the fire can be rendered ſuperior to the attractive force which holds the parts of matter united; for though to produce a fire ſufficiently ſtrong it may require better conſtructed mirrors than any at preſent made uſe of, yet we are cartain that fixity is only a relative quality, and that there is no matter abſolutely ſo, ſince heat dilates the moſt fixed bodies. Now is not this dilation the index of a beginning ſeparation, that may be augmented with a degree of heat to fuſion, and with a ſtill greater to volatiliſation?

Combuſtion ſuppoſes ſomething more than volatiliſation ; it is not ſufficient for the parts of matter to be ſufficiently ſeparated to be carried off by thoſe of heat ; they muſt alſo be of an analogous nature to fire ; without that, mercury, as well as being the moſt fluid next to air, would be alſo the moſt combuſtible, whereas experience demonſtrates, that though very volatile it is not combuſtible. Matter, in general is compoſed of four principal ſubſtances, called *elements*, that is, earth, water, air, and fire. Thoſe in which earth and water predominate will be fixed, and will only become volatile by the action of heat ; and thoſe which contain moſt air and fire will be the only real combuſtibles. The great difficulty here is clearly to evince how air and fire, both very volatile, can fix and become conſtituent parts of all bodies.

Fire, by abſorbing air, deſtroys the ſpring. Now there are only two methods of deſtroying a ſpring, either by compreſſing it till it breaks, or extending it till it loſes its effect. It is plain that fire does not deſtroy air by compreſſion, ſince the leaſt degree of heat rarefies it ; nay, by a very ſtrong heat the rarefaction of the air will occupy a ſpace thirteen times more extended than that of its general volume ;

by this means the ſpring becomes weakened, and it is in this ſtate that it can become fixed, and unite with other bodies.

Light, which falls on bodies, is not nearly reflected, but remains in quantities on the ſmall thickneſs of the ſurface which it ſtrikes; conſequently it loſes its motion, extends, is fixed, and becomes a conſtituent part of all that penetrates it. Let us add this light, tranſformed and fixed in bodies, to the above air, and to both, the conſtant and actual heat of the terreſtrial globe, whoſe ſum is much greater than that which comes from the ſun, and then it will appear to be not only one of the greateſt ſprings of the mechaniſm of Nature, but an element with which the whole matter of the globe is penetrated.

If we more particularly conſider the nature of combuſtible matters, we ſhall find, that they all proceed originally from vegetables and animals; in a word, from bodies placed on the ſurface of the globe, which the ſun enlightens, heats, and vivifies. Wood, and even coals, fat, and oil, by expreſſion, wax and ſuet, are only ſubſtances immediately from animals and vegetables. Turf, foſſil, coal, amber, liquid, or concrete bitumens, are the productions of their mixture, and their decompoſition, whoſe ulterior waſte forms ſulphurs, and the combuſtible parts of iron, tin, pyrites, and every inflammable mineral. I know, that this laſt aſſertion will not be admitted, but be rejected by thoſe who have ſtudied Nature only by the mode of chemiſtry ; but I muſt requeſt them to conſider, that their method is not that of Nature, and that it cannot even approach it without baniſhing all thoſe precarious principles, thoſe fictitious beings which they play upon, without being acquainted with them.

But, without preſſing longer on thoſe general conſiderations, let us purſue in a more direct and particular manner the examination of fire and its effects. The action of fire depends much on the manner in which it is applied ; and the effects of its motion, on ſimilar ſubſtances, will appear different according to the mode in which it is adminiſtered. I conceive fire ſhould be conſidered in three different ſtates, firſt, relative to its velocity ; ſecondly, as to its volume ; and thirdly, as to its maſs. Under each of theſe points of view, this element, ſo ſimple, and ſo uniform to all appearance, will appear extremely different. The velocity of fire is augmented without the apparent volume being increaſed, every time that in a ſpace given and filled with combuſtible matters, the action and expanſion of fire is preſſed by augmenting the velocity of the air by bellows, caverns, ventilators, aſpirative tubes, &c. all of which accelerate more or leſs the rapidity of the air directed on the fire. The action of fire is augmented by its volume, when a great quantity of combuſtible matters is accumulated, and the heat and fire is driven into the reverberatory furnaces, which comprehends thoſe of our glaſs, porcelain, and pottery manufactories, and all thoſe wherein metals and minerals are melted, iron excepted. Fire acts here by its volume, and has only its own velocity, ſince the rapidity is not augmented by the bellows, or other inſtruments which carry air to the fire.

There are many modes of augmenting the action of fire by its velocity or volume; but there is but one by which we can augment its maſs; namely, by uniting it in the focus of a burning glaſs. When we receive on the refracting, or reflecting mirror, the rays of the ſun, or even thoſe of a well-kindled fire, we unite them in ſo much the leſs ſpace, as the mirror is longer, and the focus ſhorter; for example, by a mirror of four feet diameter, and one inch focus, it is clear, that the quantity of light, or fire, which falls on the four-feet mirror, will be united in the ſpace of one inch, that is, it will be 2304 times denſer than it was, if all the incident matter arrived to this focus without any loſs, and when even the loſs is two thirds or three fourths, the maſs of fire concentrated in the focus of this mirror, will be always ſix or ſeven hundred times denſer than on the ſurface. In this, as in all other caſes, the maſs goes by the contraction of the volume; and the fire which we thus augment the denſity of, has all the properties of a maſs of matter; for, independent of the action of heat, by which it penetrates bodies, it impels and diſplaces them as a ſolid moving body which ſtrikes another would do.

Each of theſe modes of adminiſtering fire, and increaſing either the velocity, volume, or maſs, often produces very different effects on the ſame ſubſtances; inſomuch, that no reliance is to be placed on any thing that cannot be worked at the ſame time, or ſucceſſively, by all three. In the like manner, as I divide into three general proceedings the adminiſtration of this element, I divide every matter that can be ſubmitted to its action into three claſſes. Paſſing over for the preſent thoſe which are purely combuſtible, and which immediately proceed from animals and vegetables; we proceed to minerals, in the firſt claſs of which we reckon thoſe mineral matters, which this action, continued for a long time, renders lighter, as iron; in the ſecond, ſuch as it renders heavier, as lead; and in the third claſs, are thoſe matters on which, as gold, this action of fire does not appear to produce any ſenſible effect, ſince it does not at all alter their weight. All exiſting matters, that is, all ſubſtances ſimple and compounded, will neceſſarily be comprized under one of theſe three claſſes; and experiments on them by the above three proceedings, which are not difficult to be made, and only require exactneſs and time, might develope many uſeful diſcoveries, and prove very neceſſary to build on real principles the theory of chemiſtry, which has hitherto been carried on by a precarious nomenclatura, and on words the more vague as they are the more general.

Fire is the lighteſt of all bodies, notwithſtanding which it has weight, and it may be demonſtrated, that even in a ſmall volume it is really heavy, as it obeys, like all other matters, the general law of gravity, and conſequently muſt have connections or affinities with other bodies. All matters it renders more weighty will be thoſe with which it has the greateſt affinity. One of the effects of this affinity in the matters is to retain the ſubſtance even of fire, with which it is incorporated, and this incorporation ſuppoſes that fire not only loſes its heat and elaſticity, but even all its motion, ſince it fixes itſelf in theſe bodies, and becomes a conſtituent part. From which it may be imagined that there is fire under a fixed and concrete form in almoſt every body.

It is evident, that all matters, whoſe weight increaſes by the action of fire, are endowed with an attractive force ſuperior to that of the expanſion, the fiery particles of which are animated ; this being extinguiſhed the motion ceaſes, and the elaſtic and fugitive particles become fixed, and take a concrete form. Thus matters, whoſe weight is increaſed by fire, as tin, lead, &c. are ſubſtances which, by their affinity with fire, attract and incorporate. All matters, on the contrary, which, like iron, copper, &c. become lighter in proportion as they calcine, are ſubſtances whoſe attractive forces, relative to the igneous particles, is leſs than the expanſive force of fire ; this is what cauſes fire, inſtead of fixing in theſe matters, to carry off and drive away the leaſt adherent parts which cannot reſiſt its impulſion. Thoſe, which like gold, platina, ſilver, &c. neither loſe nor acquire by the application of fire, are ſubſtances which, having no affinity with fire, and not being able to unite, cannot, conſequently, either retain or accompany it when it is carried off. The matters of the two firſt claſſes clearly, therefore, have a certain degree of affinity with fire, ſince thoſe of the ſecond claſs are loaded with fire, which they retain; and the fire loads itſelf with thoſe of the firſt claſs, which it carries off; whereas the matters of the third claſs, to which it neither lends nor borrows, have not any affinity or attraction with it, but are indifferent to its action, which can neither unnaturalize nor even change them.

This diviſion of every matter into three claſſes, relative to the action of fire, does not exclude the more particular and leſs abſolute diviſion of all matters into two other claſſes, hitherto regarded as relative to their own nature, which is ſaid to be always vitrifiable, or calcareous. Our new diviſion is only a more elevated point of view, under which we muſt conſider them, to endeavour to deduce therefrom even the agent that is uſed by the relations fire can have with every ſubſtance to which it is applied.

We might ſay, with naturaliſts, that all is vitrifiable in Nature, excepting that which is calcareous: that chryſtals, precious ſtones, gres, granates, porphyries, agates, gypſums, argots, lava, pumice ſtone, with all metals and other minerals, are vitrifiable either by the fire of our furnaces or that of mirrors; whereas marble, alabaſter, chalk, marl, and other ſubſtances which proceed from the waſte ſhells and madrepores, cannot be reduced into fuſion by theſe means. Nevertheleſs, I am perſuaded that if the power of our furnaces and mirrors were farther increaſed, we ſhould be enabled to put theſe calcareous matters in fuſion; ſince there are a multiplicity of reaſons to conclude, that at the bottom their ſubſtance is the ſame, and that glaſs is the common baſis of all terreſtrial matters.

By my own experiments I have found, that the moſt powerful glaſs furnaces is only a weak fire, compared with that of bellows furnaces; and that fire produced in the focus of a good mirror, is ſtill ſtronger. I have kept iron ore for thirty-ſix hours in the hotteſt part of the glaſs furnace of Rouelle, in Burgundy, without its being melted, agglutinated, or even in any manner changed; whereas, in leſs than twelve hours this ore runs in a forge furnace. I have alſo melted, or volatilized, in a mirror many matters which neither the fire, nor reverberatory furnace, nor the moſt powerful bellows furnace could cauſe to run.

It is commonly ſuppoſed, that flame is the hotteſt part of fire, yet the contrary may be demonſtrated by the eaſieſt and moſt familiar experiments. Offer to a ſtraw fire, or even to the flame of a lighted fagot, a cloth to dry or heat, and treble the time will be required to what would be neceſſary if preſented to a braſier without flame. Newton defines flame to be a burning ſmoke, and this ſmoke, or vapour, has never the ſame quantity or intenſity of heat as the combuſtible body from which it eſcapes. By being carried upwards and extending, it has the property of communicating fire, and carrying it farther than the heat of the braſier, which alone might not be ſufficient to communicate it when even very near.

The communication of fire merits a particular attention. I found, after repeated reflections, that beſides the aſſiſtance of facts which appear to have a relation therewith, that experiments were neceſſary to underſtand the manner in which this operation of Nature is made. Let us receive two or three thouſand weight of iron in a mould at its iſſuing from the furnace; this metal in a ſhort time loſes its incandeſcence, and ceaſes from its redneſs, according to the

thickneſs

thickneſs of the ingot. If at the moment its redneſs leaves it, it is drawn from the mold, the under parts will be ſtill red, but this colour will fly off. Now, ſo long as the redneſs ſubſiſts, we can light combuſtible matters by applying them to the ingot; but as ſoon as it has loſt its incandeſcent ſtate, there are numbers of matters which it will not ſet fire to, altho' the heat which it diffuſes is, perhaps, a hundred times ſtronger than that of a ſtraw fire, which would inflame them. This flame being neceſſary to the communication of fire, I am induced to believe there is a flame in all incandeſcence. The red colour ſeems, in fact, to indicate it; and indeed I am convinced, that combuſtible, and even the moſt fixed matters, ſuch as gold and ſilver, when in an incandeſcent ſtate, are ſurrounded with a denſe flame which extends only to a very ſhort diſtance, and which is attached to their ſurface; and I can eaſily conceive, that when flame becomes denſe to a certain degree, it ceaſes from obeying the fluctuation of the air. This white or red body, which iſſues from all bodies in incandeſcence, and which ſtrikes our eyes, is the evaporation of this denſe flame which ſurrounds the body by renewing itſelf inceſſantly on its ſurface; and even the light of the ſun, which emits ſuch an amazing brightneſs, I preſume to be only an evaporation of the denſe ſtate that conſtantly plays on its ſurface; and which we muſt regard as a true flame, more pure and denſe than any proceeding from our combuſtible matters.

It is, therefore, by light that fire communicates, and heat alone cannot produce the ſame effect as when it becomes very ſtrong to be luminous. Even water, that deſtructive element to fire, by which alone we can prevent its progreſs, nevertheleſs communicates when in a well-cloſed veſſel, ſuch as Papin's digeſter, where it is penetrated with a ſufficient quantity of fire to render it luminous, and capable of melting lead and tin, whereas when it is only boiling, far from communicating fire, it extinguiſhes it immediately. It is true, that heat alone is ſufficient to prepare and diſpoſe combuſtible bodies for inflammation, by driving off the humid parts from bodies; and what is very remarkable, this heat, which dilates all bodies, does not deſiſt from hardening them by drying. I have an hundred times diſcovered, by examining the ſtones of my great furnaces, eſpecially the calcareous, they increaſed in hardneſs in proportion to the time they had undergone the heat, and they alſo at the ſame time became ſpecifically heavier. From this circumſtance, I think an induction may be drawn, which would prove, and fully confirm, that heat, although in appearance always fugitive and never ſtable in the bodies which it penetrates, nevertheleſs depoſits in a poſitive manner many parts which fixes there even in greater quantities than the aqueous and other parts which it has driven off. But what appears very difficult to be reconciled, this ſame calcareous ſtone, which becomes ſpecifically heavier by the action of a moderate heat a long time continued, becomes near a half lighter, when ſubmitted to a fire ſufficient for its calcination, and, at the ſame time, not only loſes all the hardneſs it had acquired by the action of heat, but even the natural adherence of its conſtituting parts.

Calcination generally received, is, with reſpect to fixed and incombuſtible bodies, what combuſtion is to volatile and inflammable. Calcination, like combuſtion, needs the aſſiſtance of air; it operates ſo much the quicker, as it is furniſhed with a greater quantity of that element, without which the fierceſt fire cannot calcine nor inflame any thing, except ſuch matters as contain in themſelves all the air neceſſary for thoſe purpoſes. This neceſſity for the concurrence of air in calcination, as in combuſtion, indicates, that there are more things common between them than has been ſuſpected. The application of fire is the principal of both; that of air is the ſecond cauſe, and almoſt as neceſſary as the firſt; but theſe two cauſes are equally combined, according as they act in more or leſs time, and with more or leſs power on different ſubſtances.

Combuſtion operates almoſt inſtantaneouſly, calcination is ſometimes ſo long, as to be thought impoſſible; for, in proportion as matters are more incombuſtible, the calcination is there more ſlowly made; and when the conſtituent parts of a ſubſtance, ſuch as gold, are not only incombuſtible, but appear ſo fixed as not to be volatilized, calcination produces no effect. They muſt both, therefore, be conſidered as effects of the ſame cauſe, whoſe two extremes are delineated to us by phoſphorous, which is the moſt inflammable of all bodies, and by gold, which is the moſt fixed and leaſt combuſtible. All ſubſtances compriſed between theſe two extremes, will be more or leſs ſubjected to the effects of combuſtion and calcination, according as they approach either of them; inſomuch, that in the middle points there will be found ſubſtances that endure an almoſt equal degree of both; from which we may conclude, that all calcination is always accompanied with a little combuſtion, and all combuſtion with a little calcination. Cinders, and other reſidue of the moſt combuſtible matters, demonſtrate that fire has calcined all the parts it has not burned, and conſequently, a little calcination is found here with combuſtion. The ſmall flame which riſes from moſt matters, that are calcined, demonſtrates alſo that a ſlight combuſtion is made. Thus, we muſt not ſeparate theſe two effects, if we would find out the reſults of the action of fire on the different ſubſtances to which it is applied.

But it may be ſaid, that combuſtion always diminiſhes the volume or maſs, by reaſon of the quantity of matter it conſumes; and that calcination increaſes the weight of many ſubſtances. Such an objection appears well-founded, and deſerves an anſwer, eſpecially as this is the moſt difficult point of the queſtion. For that purpoſe let us conſider a matter in which we ſhall ſuppoſe one half to be fixed parts, and the other volatile or combuſtible. By the application of fire to this all the volatile or combuſtible parts will be raiſed up or burnt, and conſequently ſeparated from the whole maſs ; from hence this maſs or quantity of matter will be found diminiſhed one half, as we ſee it in calcareous ſtones, which loſe near half their weight in the fire. But if we continue to apply the fire for a very long time to the other half, compoſed of fixed parts, all combuſtion and volatilization being ceaſed, that matter, inſtead of continuing to loſe its maſs, muſt encreaſe at the expence of the air and fire with which it is penetrated; and thoſe are matters already calcined, and prepared by Nature to the degree where combuſtion ceaſes, and conſequently ſuſceptible to augment the weight from the firſt moment of the application. We have ſeen, that light extinguiſhes on the ſurface of all bodies which do not reflect ; and that heat, by long reſidence, fixes partly in the matters which it penetrates ; we know that air is neceſſary for calcination, or combuſtion, and the more ſo for calcination as matters have more fixity in the external parts of bodies, and become a conſtituent part ; hence, it is natural to imagine, that this augmentation of weight proceeds only from the addition of the particles of light, heat, and air, which are at length fixed and united to one matter, againſt which they have made ſo many efforts, without being able either to raiſe or burn them. This appears clearly to be the fact, for if we afterwards preſent a combuſtible ſubſtance to them they will quit the fixed matter, to which they were only attached through force, retake their natural motion, elaſticity, and volatility, and all depart with it; from hence, metal, or calcinized matter, to which theſe volatile parts has been rendered, retakes its priſtine form, and its weight is found diminiſhed by the whole quantity of fiery and airy particles which were fixed in it, and which had been juſt raiſed by this new combuſtion. All this is performed by the ſole law of affinities; and there ſeems to be no more difficulty to conceive how the lime of a metal is reduced, than to underſtand how it is precipitated in diſſolution; the cauſe is the ſame, and the effects are ſimilar. A metal diſſolved by an acid, will precipitate when to this acid another ſubſtance is offered with which it has more affinity than metal, the acid then quits it and falls to the bottom. So, likewiſe, this metal calcines, that is, loaded with parts of air, heat, and fire, which being fixed, keeps it under the form of a lime, and will precipitate, or be reduced, when preſented to this fire and fixed air, from the combuſtible matters with which they have more affinity than with the metal; the latter will retake its firſt form as ſoon as it is diſembarraſſed from this ſuperfluous air and fire, at the expence of the combuſtible matters offered to it, and the volatile parts it had loſt.

I think I have now demonſtrated, that all the little laws of chemical affinities, which appeared ſo variable and different, are no other than the general laws of attraction, common to all matter. That this great law, always conſtant and the ſame, appeared only to vary by its expreſſion, which cannot be the ſame when the figure of bodies enters, like an element, into their diſtance. With this new key we can unlock the moſt profound ſecrets of Nature ; we can attain the knowledge of the figure of the primitive parts of different ſubſtances ; aſſign the laws and degrees of their affinities ; determine the forms which they take by re-uniting, &c. I think alſo, I have made it appear that impulſion depends on attraction ; and that, although it may be conſidered as a different force, it is, notwithſtanding, a particular effect of this ſole and general one. I have conſidered the communication of motion as impoſſible any otherwiſe than by a ſpring, from whence I have concluded, that all bodies in Nature are more or leſs elaſtic, and that there is not one perfectly hard; that is, entirely deprived of a ſpring, ſince all are ſuſceptible of receiving motion. I have endeavoured to ſhew how this ſole force may change direction, and the attraction become at once repulſive; and from theſe oppoſite principles, which are all founded on rational mechanics, I have ſought to reduce the principal operations of Nature, ſuch as the production of light, heat, and fire, and their action on different ſubſtances; this laſt object which intereſts us the moſt in a vaſt field, but of which I can only cultivate a little ſpot, yet I preſume I may render ſome aſſiſtance, by putting into more capable and laborious hands the inſtruments I made uſe of. Theſe inſtruments were the three modes of making uſe of fire, that is, by its velocity, volume, and maſs; by applying it concurrently to the three claſſes of ſubſtances, which either loſe, gain, or are not affected by the application of fire.

OF AIR, WATER, AND EARTH.

BY our former obſervations it appears that air is the neceſſary and firſt food of fire, which can neither ſubſiſt nor propagate but by what it aſſimilates, conſumes, or carries off, of that element, whereas, of all material ſubſtances, air is that which ſeems to exiſt the moſt independently of the aid or preſence of fire, for although it habitually has nearly the ſame heat as other matters it can do without it, and requires infinitely leſs than any of the reſt to ſupport its fluidity, ſince the moſt exceſſive cold cannot deprive it of that. The ſtrongeſt condenſations are not capable of breaking its ſpring; the active fire, in combuſtible matters, is the only agent which can alter its nature by rarefying and extending its ſpring to the point of rendering it ineffectual, and thus deſtoying its elaſticity. In this ſtate, and in all the links which precede, the air is capable of re-aſſuming its elaſticity, in proportion as the vapours of combuſtible matters evaporate and ſeparate from it. But if the ſpring has been totally weakened and extended, that it cannot re-inſtate itſelf, from having loſt all its elaſtic power, the air of the volatile part, which was before a fixed ſubſtance that incorporated with other ſubſtances, would make a conſtituent part of all thoſe to which it unites by contact. Under this new form it can no longer forſake the fire, but to unite, like fixed matter, to other fixed matters; and if there remains ſome parts inſeparable from fire they then make a portion of that element, ſerve it for a baſe, and are depoſited with it in the ſubſtance they heat and penetrate together. This effect is manifeſted in all calcinations, and is the more ſenſible as the heat is longer; but combuſtion demands only a ſmall time to completely effectuate the ſame. If we wiſh to haſten calcination the uſe of bellows may be neceſſary, not ſo much to augment the heat of the fire as to eſtabliſh a current of air on the ſurface of the matters; yet it is not requiſite for the fire to be very fierce to deprive air of its elaſticity, for a very moderate heat, when conſtant applied on a ſmall quantity, is ſufficient to deſtroy the ſpring; and for this air, without ſpring, to fix itſelf afterwards in bodies, there is only a little more or leſs time required, according to the affinity it may have under this new form, with the matters to which it unites. The heat of the body of animals or vegetables is ſufficiently powerful to produce this effect. The degrees of heat are different in different kinds of animals: birds are the hotteſt, from which we paſs ſucceſſively to quadrupeds, man, cetaceous, animals, reptiles, fiſh, inſects, and laſtly, to vegetables, whoſe heat is ſo trifling as to have made moſt naturaliſts declare they had not any, although it is very apparent, and in winter ſurpaſſes that of the atmoſphere. I have obſerved on a great number of trees, cut in cold weather, that their internal part was ſenſibly warm, and that this heat remained for many minutes. This heat is only moderate while the tree is young and ſound, but as ſoon as it grows old the heart heats by the fermentation of the pith, which no longer circulates there with the ſame freedom; and as ſoon as this heat begins the centre receives a red tint, which is the firſt index of the periſhing ſtate of the tree, and the diſorganization of the wood. The reaſon naturaliſts have not found there was a difference between the temperature of the air and the heat of vegetables is, becauſe they have made their obſervations at a bad time of the year, and not paid attention, that in the ſummer the heat of the air exceeds that of the internal part of a tree; whereas in winter it is quite the contrary. They have not remembered that the roots have conſtantly the degrees of heat which ſurrounds them, and that this heat of the internal part of the earth is, during all winter, conſiderably greater than that of the air, and the ſurface of the earth. They did not conſider that the motion alone of the pith, already warm, is a neceſſary cauſe of heat, and that this motion, increaſing by the action of the ſun, or by an external heat, that of vegetables muſt be ſo much the greater as the motion of their pith is more accelerated, &c.

Here the air contributes to the animal and vital heat, as we have ſeen that it does to the action of fire in combuſtible and calcinable matters. Animals, which have changes, and reſpire air, have more heat than thoſe deprived of it; and the more the intertal ſurface of the lungs is extended, and ramified in a greater number of cells, the more it preſents greater ſuperficies to the air which the animal draws by inſpiration; the more alſo its blood becomes hotter, the more it communicates heat to all parts of the body it nouriſhes, and this proportion takes place in all known animals. Birds, relatively to the volume of their body, have lungs conſiderably more extended than man or quadrupeds. Reptiles, even thoſe with a voice, as frogs, inſtead of lungs have a ſimple bladder. Inſects which have little or no blood pump the air only by ſome pipes, &c. Thus by taking the degree of the temperature of the earth for the term of compariſon, I have obſerved that this heat being ſuppoſed ten degrees, that of birds was nearly thirty-three, that of ſome quadrupeds more than thirty-one and a half, that of man thirty and a half, or thirty-one, whereas that of frogs is only fifteen or ſixteen, and that of fiſhes and inſects only eleven or twelve, which is nearly the ſame as that of vegetables. Thus the degree of heat in man and animals depends on the force and extent of the lungs; theſe are the bellows of the animal machine: the only difficulty is to conceive how they may carry the air on the fire which animates us, a fire whoſe focus ſeems to be indeterminate; a fire that has not even been qualified with this name, becauſe it is without flame or any apparent ſmoke, and its heat is only moderate and uniform. However, if we conſider that heat and fire are the effects, and even the elements of the ſame claſs; that heat rarefies air, and that, by extending its ſpring, it may render it without effect; we may imagine, that the air drawn by our lungs will be greatly rarefied, loſe its ſpring in the bronchia and little veſicles, where it ſoon will be deſtroyed by the arterial and venous blood, for theſe blood-veſſels are ſeparated from the pulmonary veſicles by ſuch thin diviſions that the air eaſily paſſes into the blood, where it produces the ſame effect as upon common fire, becauſe the heat of this blood is more than ſufficient to deſtroy the elaſticity of the particles of air, and to drag them under this new form into all the roads of circulation. The fire of the animal body differs little from common fire, excepting the degree of heat is leſs; from hence there is no flame, becauſe the vapours, which repreſent the ſmoke, have not heat enough to inflame; every other effect is the ſame: the reſpiration of a young animal abſorbs as much air as the light of a candle, for if incloſed in veſſels of equal capacities the animal dies in the ſame time as the candle extinguiſhes: nothing can more evidently demonſtrate that the fire of the animal and that of the candle are not only of the ſame claſs but of the ſame nature, and to which the aſſiſtance of the air is equally neceſſary.

Vegetables, and moſt inſects, inſtead of lungs, have only aſpiratory tubes, by which they pump up the air that is neceſſary for them; it paſſes in very ſenſible balls into the pith of the vine. The air is not only pumped up by the roots but often even by the leaves, and forms a very eſſential part of the food of the vegetable which aſſimilates, fixes, and preſerves it. Experience fully confirms all we have advanced on this ſubject, and that all combuſtible matters contain a conſiderable quantity of fixed air, as do alſo all animals and vegetables, and all their parts, and the waſte which proceeds therefrom; and that the greateſt number likewiſe include a certain quantity of elaſtic air. And, notwithſtanding the chimerical ideas of ſome chemiſts, reſpecting phlogiſton, there does not remain the ſmalleſt doubt but that fire or light produces, with the aſſiſtance of air, all the effects thereof.

Minerals, which like ſulphur and pyrites, contain in their ſubſtance a quantity of the ulterior waſte of animals and vegetables, include from thence combuſtible matters, which contain more or leſs fixed air, but always much leſs than the purely animal or vegetable ſubſtances. We can drive from them this fixed air by combuſtion. In animal and vegetable matters it is diſengaged by ſimple fermentation, which, like combuſtion, has always need of air for its operation. Sulphurs and pyrites are not the only Minerals which muſt be looked upon as combuſtible, there are many others, which I ſhall not here enumerate, becauſe it is ſufficient to remark, their degree of combuſtion depends commonly on the quantity of ſulphur which they contain. All combuſtible minerals originally derive this property either from the mixture of animal or vegetable parts which are incorporated with them, or from the particles of light, heat, and air, which, by the lapſe of time, are fixed in their internal part. Nothing, according to my opinion, is combuſtible but that which has been formed by gentle heat, that is, by theſe ſame elements combined in all the ſubſtances which the ſun brightens and vivifies, or in that which the internal heat of the earth foments and unites.

The internal heat of the globe of the earth, of which we have already treated, is always ſubſiſting and conſtant: it enters, like an element, into all the combinations of the other elements, and is more than ſufficient to produce the ſame effects on air as actual fire on animal heat; conſequently this internal heat of the earth will deſtroy the elaſticity of the air, and render it fixed, which being divided into minute parts will enter into a great number of ſubſtances, from hence they will contain particles of fixed air and fire, which are the firſt principles of combuſtibility ; but they will be found in different quantities, according to their degree of affinity with the ſubſtance, and this degree will greatly depend on the quantity theſe ſubſtances contain of animal and vegetable parts, which appear to be the baſe of all combuſtible matter. Moſt metallic minerals, and even metals, contain great quantities of combuſtible parts ; zinc, antimony, iron, copper, &c. burn and produce a very briſk flame, as long as the combuſtion of theſe inflammable parts remain, after which, if the fire is continued, the calcination begins, during which there enters into them new parts of air and heat, which fixes, and cannot be diſengaged but by preſenting to them combuſtible matters, with which they have a greater affinity than with thoſe of the mineral, with which they are only united by the effort of calcination. It ſeems, therefore, that the converſion of metallic ſubſtances into droſs, and their reduction, might be very clearly underſtood without applying to ſecondary princples, or arbitrary hypotheſes, for their explanation.

Having conſidered the action of fixed air in the moſt ſecret operations of nature, let us take a view of it when it reſides in bodies under an elaſtic form ; its effects are then as variable as the degrees of its elaſticity, and its action, tho' always the ſame, ſeems to give different products in different ſubſtances. To bring this conſideration back to a point of general view, we will compare it with water and earth, as we have already compared it with fire ; the reſults of this compariſon between the four elements will afterwards be eaſily applied to every ſubſtance, ſince they are all only compoſed of theſe four real principles.

The greateſt cold that is known, cannot deſtroy the ſpring of the air, and the leaſt heat is ſufficient for that purpoſe. Between the ſtate of fixity, and that of perfect elaſticity, there is, however, all the links of the intermediate ſtates, in one of which it always reſides in earth and water, and all the ſubſtances which are compoſed of them ; for example, water, which appears ſo ſimple a ſubſtance, contains a certain quantity of air, which is neither fixed nor elaſtic, as is plain from its congelation, ebullition, and reſiſtance to all compreſſion, &c. Experimental phyſic demonſtrates, that water is incompreſſible, for inſtead of ſhrinking and entering into itſelf when preſſed, it paſſes through the moſt ſolid and thickeſt veſſels; which could not be the caſe if the air it contained was in its ſtate of full elaſticity. The air contained therefore in water, is not ſimply mixed therewith, but is united in a ſtate where its ſpring is not ſenſibly exerciſed; yet the ſpring is not entirely deſtroyed, for if we expoſe water to congelation, the air iſſues from its internal part, and unites on its ſurface in elaſtic bubbles. This alone ſuffices to prove, that air is not contained in water under its common form, ſince being ſpecifically 850 times lighter, it would be forced to iſſue out by the ſole neceſſity of the preponderance of water; neither under an affixed form, but only in a medium ſtate, from whence it can eaſily re-take its ſpring, and ſeparate more eaſily than from every other matter.

It may be objected that cold and heat never operate in the ſame mode, and that if one of theſe cauſes gives to air its elaſticity, the other muſt deſtroy it, and I own that in general it is ſo, but in this particular they produce the ſame effect. It is well known that water, frozen or boiled, retakes the air it had loſt as ſoon as it is liquified or cooled. The degree of affinity of air with water depends, therefore, on its temperature, which in its liquid ſtate, is nearly the ſame as that of the general heat to the ſurface of the earth: the air with which it has much affinity penetrates it as ſoon as it is divided into ſmall parts, yet the degree of elementary and general heat, weakens their ſpring ſo as to render them ineffectual as long as the water preſerves this temperature; but if the cold penetrates, or this degree of heat diminiſhes, then its ſpring will be re-eſtabliſhed by the cold, and the elaſtic bubbles will riſe to the ſurface of the water ready to freeze; if, on the contrary, the temperature of the water is increaſed by an external heat, the integrant parts become too much divided, they are rendered volatile, and the air with which they are united, riſes and eſcapes with them. Water and air have much greater connections between them than oppoſite properties, and as I am well perſuaded, that all matter is convertible, and that the elements may be transformed, I am inclined to believe, that water can change into air when ſufficiently rarefied to raiſe up in vapours, for the ſpring of the vapour of the water is even more powerful than the ſpring of the air.

Experience has taught me that the vapours of water can increaſe the fire in the ſame manner as common air; and this air, which we ſhould regard as pure, is always mixed with a very great quantity of water: but it muſt be remarked, that the proportions of the mixtures is not nearly the ſame in theſe two elements. It may be ſaid in general that there is much leſs air in water than water in air. In conſidering this proportion we muſt refer to the volume and maſs. If we eſtimate the quantity of air contained in water by the volume it will appear nil, ſince the volume is not in the leaſt increaſed. Thus it is not to the volume that we muſt relate this proportion, it is alone to the maſs, that is, to the real quantity of matter in one and the other of theſe two elements that we muſt compare that of their mixture, by which we ſhall perceive that the air is much more *aqueous* than the water is *ærial*, perhaps in proportion of the maſs, that is, eight hundred and fifty times. Be this eſtimation either too ſtrong or too weak we can derive this induction from it, that water muſt change more eaſily into air than air can transform into water. The parts of air, although ſuſceptible of being extremely divided, appear larger than thoſe of water, ſince the latter paſſes through many fibres which air cannot penetrate; ſince the vapours of water are only raiſed to a certain height in the air; and, in ſhort, ſince air ſeems to imbibe water like a ſponge, to contain it in a large quantity, and that the container is certainly greater than the contained.

In the order of the converſion of the elements it appears, that water is to air what air is to fire, and that all the transformations of nature depend on them. Air, like the food of fire, aſſimilates with it, and is transformed into this firſt element. Water, rarefied by heat, is transformed into a kind of air capable of feeding the fire like common air. Thus fire has a double fund of certain ſubſiſtence, if it conſumes much air it can alſo produce much by the rarefaction of water, and thus repair, in the maſs of atmoſphere, all the quantity it deſtroyed, while ulteriorly it converts itſelf with air into fixed matter in the terreſtrial ſubſtances which it penetrates by its heat or by its light. And ſo, likewiſe, as from one part water is converted into air, or into vapours, as volatile as air, by its rarefaction, it is converted into a ſolid ſubſtance by a kind of condenſation. Every fluid is rarefied by heat and condenſed by cold. Water follows this common law, and condenſes in proportion as it grows colder. Let a glaſs tube be filled three parts full and it will deſcend in proportion as the cold increaſes, but ſome time before congelation it will aſcend above the point of three fourths of the height of the tube, and increaſe ſtill more conſiderably by being frozen. But if the tube is well ſtopped, and perfectly at reſt, the water will continue to lower, and will not freeze, although the degree of cold is ſix, eight, or ten degrees below the freezing point; congelation, therefore, preſents, in an inverted manner, the ſame phenomena as inflammation. An heat, however great, ſhut up in a well-cloſed veſſel, will not produce inflammation unleſs touched with an inflamed matter; ſo, likewiſe, to whatſoever degree a fluid is cooled, it will not freeze unleſs it touches ſomething already frozen. The particles of water, which are frozen in the external air, or in the air contained in the tube, when it is ſhaken or unſtopped, ſtrikes the ſurface of the water, and communicates their ice to it. In inflammation the air, at firſt very much rarefied by heat, loſes its volume, and fixes itſelf ſuddenly. In congelation, water, at firſt condenſed by the cold, takes a larger volume, and fixes itſelf likewiſe, for ice is a ſolid ſubſtance, lighter than water, and would preſerve its ſolidity if the cold continued the ſame; and I am inclined to believe that we ſhould attain the point of fixing mercury at a leſs degree, by ſublimating it into vapours in a very cold air;

air ; and alſo that water, which only owes its liquidity to heat, would become a ſubſtance much more ſolid and fuſible, as it would endure a ſtronger and a longer time the rigour of the cold.

But without ſtopping on this idea, that is, without admitting or excluding the poſſibility of the converſion of the ice into infuſible matter, or fixed and ſolid earth, let us paſs on to more extenſive views on the modes Nature makes uſe of for the transformation of water. The moſt powerful and moſt evident is the animal filter. The body of ſhell-animals, by feeding on the particles of water, labours, at the ſame time, on the ſubſtance to the point of unnaturalizing it. The ſhell is certainly a terreſtrial ſubſtance, a true ſtone, from which all the ſtones called *calcareous*, and many other matters, derive their origin. This ſhell appears to make the conſtitutive part of the animal it covers, ſince it is perpetuated by generation, for it is on the ſmall ſhell-animal juſt come into exiſtence as well as on thoſe which have arrived at their full growth ; but this is no leſs a terreſtrial ſubſtance, formed by the ſecretion or exudation of the body, for it increaſes and thickens by rings and layers in proportion as the animal grows ; and this ſtony matter often exceeds fifty or ſixty times the maſs of the body which produces it. Let us, for a moment, reflect on the number of the kinds of ſhell-animals, or rather of thoſe animals with a ſtony tranſudation; they, poſſibly, are more numerous in the ſea than the inſect kind are upon earth. Let us afterwards repreſent their full growth, their prodigious multiplication, and the ſhortneſs of their lives, which we may ſuppoſe does not exceed ten years; let us afterwards conſider that we muſt multiply by fifty or ſixty the almoſt immenſe number of the individuals of this claſs to form an idea of all the ſtony matter produced in ten years; then that this block muſt be augmented with as many ſimilar blocks as there are as many times ten in all the ages from the beginning of the world, and we ſhall familiarize ourſelves by this idea, that all our coral, rocks of calcareous ſtone, marble, chalk, &c. originally proceeded alone from the caſt-off coats of thoſe little animals.

Salts, bitumen, oil, and the greaſe of the ſea, enter little or none into the compoſition of the ſhell; neither does the calcareous ſtone contain any of thoſe matters; this ſtone is, therefore, only water transformed, joined to ſome little portion of vitrifiable earth, and a great quantity of fixed air, which may be diſengaged therefrom by calcination; which operation produces the ſame effects on the ſhells taken in the ſea as upon thoſe drawn out of quarries; they both form lime, with only a little difference in their quality. Lime, made with oyſter or other ſhells, is weaker than that made with hard ſtone; but the proceſs of Nature is the ſame, as are the reſults of its operation. Shells and ſtones, alike nearly loſe half their weight by the action of fire in calcination; the water iſſues firſt, after which the fixed air is diſengaged, and then the fixed water, of which theſe ſtony ſubſtances are compoſed, retakes its firſt nature, is elevated into vapours, drove off and rarefied by the fire, ſo that there remains only the moſt fixed parts of this air and water, which, perhaps, are ſo ſtrongly united in themſelves, and to the ſmall quantity of the fixed earth of the ſtone, that the fire cannot ſeparate them; the maſs, therefore, is reduced nearly an half, and would probably be ſtill more if ſubmitted to a ſtronger fire. And what appears to prove that this matter, driven out of the ſtone by the fire, is nothing elſe than air and water, is the avidity with which calcined ſtone ſucks up the water given to it, and the force with which it draws water from the atmoſphere. Lime, by expoſure either in air or water, in a great meaſure regains the maſs it had loſt by calcination ; the water, with the air it contains, replaces that which the ſtone contained before. Stone then retakes its firſt nature, for in mixing lime with the remains of other ſtones, a mortar is made which hardens, and becomes a ſolid ſubſtance, like thoſe from which it is compoſed.

Thus, then, we ſee on the one hand all the calcareous matters, the origin of which we muſt refer to animals; and on the other, all the combuſtible matters proceeding from animal or vegetable ſubſtances; they together occupy a great ſpace on the earth; yet, however great their number may be, they only form a ſmall part of the terreſtrial globe, the principal foundation of which, and the greateſt quantity conſiſts in one matter of the nature of glaſs; a matter we muſt look upon as terreſtrial element, to the excluſion of all other ſubſtances, to which it ſerves as a baſe, like earth, when it forms vegetables by the means, or remains of animals, and by the transformation of the other elements; and it is alſo the ulterior term to which we can return or reduce them all.

It appears that the animal filter converts water into ſtone ; the vegetable filter can alſo transform it, when all the circumſtances are found to be the ſame. The heat of vegetables and the organs of life being leſs powerful than thoſe of ſhell animals, the vegetable cannot produce but a ſmall quantity of ſtones, which are frequently found in its fruits; but it can and does convert a great quantity of air, and a ſtill greater of water into its ſubſtance. The fixed earth it appropriates, and which ſerves as a baſe to theſe two elements, does not make the hundredth part of its maſs ; hence, the vegetable is almoſt entirely compoſed of air and water, transformed into wood, or a ſolid ſubſtance, which is afterwards reduced into earth by combuſtion and putrefaction. The ſame may be ſaid of animals ; they not only fix and transform air and water, but fire, and in a much greater quantity than vegetables. It appears, therefore, that the functions of organized bodies are the moſt powerful means made uſe of by Nature for the converſion of the elements. We may look on each animal, or vegetable, as a ſmall particular centre of heat or fire that appropriates to itſelf the air and water which ſurround it, aſſimilates them to vegetate or nouriſh, and live on the productions of the earth, which are themſelves only air and water precedently fixed. It alſo appropriates to itſelf a ſmall quantity of earth, and receiving the impreſſions of light, the heat of the ſun and terreſtrial globe, it converts into its ſubſtance all theſe different elements; works, combines, unites, and oppoſes them, till they have undergone the neceſſary form towards its ſupport of life, and the growth of organization, the mold of which once given, models every matter it admits, and from inanimate renders it organized.

Water, which ſo readily unites, and enters with air into organized bodies, unites alſo with ſome ſolid matters, ſuch as ſalts; and it is often by their means that it enters into the compoſition of minerals. Salt at firſt appears to be only an earth ſoluble in water, and of a ſharp ſavour, but chemiſts have perfectly diſcovered, that it principally conſiſts in the union of what they term the *earthy* and the *aqueous principle*. The experiment of the nitrous acid, which after combuſtion only leaves a ſmall quantity of earth and water, has cauſed them to think, that ſalt was compoſed only of theſe two elements; yet I think it is eaſily to be demonſtrated, that air and fire alſo enter their compoſition; ſince nitre produces a great quantity of air in combuſtion, and this fixed air ſuppoſes fixed fire which diſengages at the ſame time: beſides all the explanations given of the diſſolution cannot be ſupported, and it would be againſt all analogy, that ſalt ſhould be compoſed only of theſe two elements, while all other ſubſtances are compoſed of four. The experiments of Mr. Hales demonſtrate, that vitriol and marine ſalt contain much fixed air; that nitre contains ſtill much more, even to the eighth of its weight; and that ſalt of tartar contaius ſtill more than thoſe. But this does not ſupport the idea that ſalt is the mediate ſubſtance between earth and water; theſe two elements enter in different proportions into the different ſalts, or ſaline ſubſtances, whoſe variety and number are ſo great, as not to be enumerated; but which, generally preſented under the denomination of acids and alkalis, ſhews us, that there is in general more earth than water in the laſt, and more water than earth in the firſt.

Nevertheleſs, water, although intimately mixed with ſalts, is neither fixed nor united there by a ſufficient force to transform into a ſolid matter; it renders it ſalt or acid under its primitive form, and the beſt concentrated acid, or the moſt deprived of water, which might be looked upon as liquid earth, only owes its liquidity to the quantity of the air and fire it contains; and it is no leſs certain, that they are indebted for their ſavour to the ſame principles. An experiment, which I have frequently tried, has fully convinced me, that alkali is produced by fire. Lime made accordiug to the common mode, and put upon the tongue, even before ſlacked by air or water, has a ſavour which indicates the preſence of a certain quantity of alkali. If the fire is continued, this lime by longer calcination, becomes more poignant; and that drawn from furnaces, where the calcination has ſubſiſted for five or ſix months together, is ſtill more ſo. Now this ſalt could not be contained in the ſtone before its calcination, ſince it augmented in proportion to the ſtrength and continuance of the fire; but it is evident, the fire is the immediate product of the fire and air, which incorporate in the ſubſtance during its calcination, and which, by this means, are become fixed parts thereof, and from which they have driven moſt of the watry molecules it before contained. This alone appeared to me ſufficient to pronounce that fire is the principal of the formation of the mineral alkali; and we may conclude, by analogy, that

other

other alkalis owe their formation to the conſtant heat of the animal and vegetable from which they are drawn.

With reſpect to acids, although the demonſtration of their formation by fire and fixed air, is not ſo immediate, it does not appear leſs certain. We have proved, that nitre and phoſphorus draw their origin from vegetable and animal matters ; and that vitriol comes from pyrites, ſulphur and other combuſtibles. It is likewiſe certain that acids, whether vitriolic, nitrous, or phoſphorical, always contain a certain quantity of alkali ; we muſt, therefore, refer their formation and ſavour to the ſame principle, and by reducing the varieties of both to one of each, bring back all ſalts to one common origin : thoſe which contain moſt of the active principles of air and fire, will neceſſarily have the moſt power and taſte. I underſtand by power the force with which ſalts appear animated to diſſolve other ſubſtances. Diſſolution ſuppoſes fluidity, and as it never operates between two dry or ſolid matters, it alſo ſuppoſes the principle of fluidity in the diſſolvent, that is, fire ; the power of the diſſolvent will be, therefore, ſo much the greater, as on one part it contains more of this active principle; and, on the other hand, its aqueous and terrene parts will have more affinity with thoſe of the ſame kind contained in the ſubſtances to diſſolve; and, as the degrees of affinity vary, we muſt not be ſurprized at different ſalts varying in their action on different ſubſtances; their active principle is the ſame, their diſſolving power the ſame; but they remain without exerciſe when the ſubſtance preſented repels that of the diſſolvent, or has no degree of affinity with it; but the contrary is the caſe when there is ſufficient force of affinity to conquer that of the coherence; that is, when the active principles, contained in the diſſolvent, under the form of air and fire, is found more powerfully attracted by the ſubſtance to be diſſolved, than they are by the earth and water they contain. Newton is the firſt who has given affinities for the cauſes of chemical precipitation; Stahl adopted and tranſmitted this idea; and it appears to be at preſent univerſally received as a truth. But neither Newton nor Stahl ſaw that all theſe affinities, ſo different in appearance, are only particular effects of the general force of univerſal attraction: and, in defect of this view, their theory cannot be complete, becauſe they were obliged to ſuppoſe as many trivial laws of different affinities, as there were different phenomena.

Salts concur in many operations of Nature by the power they have of diſſolving other ſubſtances; for, altho' it is commonly ſaid, that water diſſolves ſalt, it is eaſy to be perceived, that in reality, when there is a diſſolution, both are active, and may be alike called *diſſolvents*. Regarding ſalt as only a diſſolvent, the body to be diſſolved may be either liquid or ſolid; and, provided the parts of the ſalt be ſufficiently divided to touch immediately thoſe of the other ſubſtances, they will act and produce all the effects of diſſolution. By this we ſee how much the action of ſalts, and the action of the element of water which contains them, muſt have influence on the compoſition of mineral matters. Nature may produce by this mode, all that our arts produce by that of fire. Time only is required for ſalts and water to operate on the moſt compact and hard ſubſtances, ſo as to render them capable of uniting with all analogous ſubſtances, and to ſeparate from all others; but this time, which to Nature is never wanting, is, of all things, that which is the moſt deficient to us: the greateſt of all our arts, therefore, is that of abridging time, that is, to effect that in one day, what Nature takes an age to perform.

However vain this pretenſion may appear, we muſt not entirely renounce it, for has not man diſcovered the mode of creating fire, of applying it to his uſe, and by the means of this element to ſuddenly diſſolve thoſe bodies by fuſion which would take up a conſiderable period by any other means?

We muſt not, however, conclude that Nature really performs by the means of water all that we do by fire. The decompoſition of every ſubſtance is only to be made by diviſion, and the greater this diviſion the more the decompoſition will be complete. Fire ſeems to divide as much as poſſible thoſe matters it puts in fuſion; nevertheleſs it may be doubted whether thoſe which water and acids keep in diſſolution are not ſtill more divided, and the vapours raiſed by heat contain matters ſtill further attenuated. In the bowels of the earth, then, by the means of the heat it includes, and the water which inſinuates, there is made an infinity of ſublimations, diſtillations, chryſtalizations, aggregations, and disjunctions, of every kind. By time all ſubſtances may be compounded and decompounded by theſe means; water may divide and attenuate the parts more than fire when it melts them, and thoſe attenuated parts will join in the ſame manner as thoſe of fuſed metal unite by cooling. Chryſtalization, of which the ſalts have given us an idea, is never performed but when a ſubſtance, being diſengaged from every other, is much divided and ſuſtained by a fluid, which having little or no affinity with it, permits it to unite and form, by virtue of its force of attraction, maſſes of a figure nearly ſimilar to its primitive parts. This operation, which ſuppoſes all the above circumſtances, may be done by the intermediate aid of fire as well as by that of water, and is often accompliſhed by the concurrence of both, becauſe all this exacts but one diviſion of matter ſufficiently great for its primitive parts to be able to form, by uniting figured bodies like themſelves. Now fire can bring many ſubſtances to this ſtate much better than any other diſſolvent, as obſervation demonſtrates to us in aſbeſtos, and other productions of fire, whoſe figures are regular, and which muſt be looked upon as true chryſtalizations. Yet this degree of diviſion, neceſſary to chryſtalization, is not the greateſt poſſible, ſince in this ſtate the ſmall parts of matter are ſtill ſufficiently large to conſtitute a maſs, which, like other maſſes, is only obedient to the ſole attractive force, and the volumes of which, only touching in points, cannot acquire the reſultive force that a much greater diviſion might perform by a more immediate contact, and this is what we ſee happen in efferveſcences, where at once heat and light are produced by the mixture of two cold liquors.

Light, heat, fire, air, water, and ſalts, are ſteps by which we deſcend from the top of Nature's ladder to its baſe, which is fixed earth. And theſe are the only principles that we muſt admit and combine for the explanation of all phenomena. Theſe principles are real, independent of all hypotheſes and all method, as are alſo their converſion and transformation. It is the ſame with the element of earth, it can convert itſelf by volatilizing and taking the form of the other elements, as thoſe take that of earth in fixing; it, therefore, appears quite uſeleſs to ſeek for a ſubſtance of pure earth in terreſtrial matters. The tranſparent luſtre of the diamond dimmed the ſight of our chemiſts, when they conſidered that ſtone as a pure elementary fire; they might have ſaid, with as much foundation, that it is pure water, all the parts of which are fixed to compoſe a ſolid diaphanous ſubſtance. When we would define Nature the large maſſes ſhould alone be conſidered, and thoſe elements have been well taken notice of by even the moſt ancient philoſophers.

ſophers. The ſun, atmoſphere, earth, ſea, &c. are all great maſſes on which they eſtabliſhed all their concluſions; and if there ever had exiſted a planet of phlogiſton, an atmoſphere of alkali, an ocean of acid, or a mountain of diamonds, ſuch might have been looked upon as the general and real principles of all bodies, but they are only particular ſubſtances, produced, like all the reſt, by the combinations of true elements; and ideas to the contrary would never have been ſtarted but upon the ſuppoſition that the earth was neither more ſimple nor leſs convertible than either of the other elements.

In the great maſs of ſolid matter, which the earth repreſents, the ſuperficial is the leaſt pure. All matters depoſited by the ſea, in form of ſediment, all ſtones produced by ſhell-animals, all ſubſtances compoſed by the combinations of the waſte of the animal or vegetable kingdom, and all thoſe which have been changed by volcanean fires, or ſublimated by the internal heat of the globe, are mixed and transformed ſubſtances; and altho' they compoſe great maſſes they do not clearly repreſent the element of earth. They are vitrifiable matters, whoſe maſs is one hundred thouſand times more conſiderable than vitreous ſubſtances, which ſhould be regarded as the true baſis of this element.

It is from this common foundation all other ſubſtances have derived the origin of their ſolidity, for all fixed matter, ever ſo much decompoſed, reduces ulteriorly into glaſs by the ſole action of fire: it retakes its firſt nature, when diſengaged from the fluid, or volatile matters, which were united with it; and this glaſs, or vitreous matter, which compoſes the maſs of our globe, ſo much the better repreſents the element of earth, as it has neither colour, odour, taſte, liquidity, nor fluidity, qualities which all proceed from the other elements, or belong to them.

If glaſs is not preciſely the element of earth, it is at leaſt the moſt ancient ſubſtance thereof; metals are more recent, and moſt other minerals form within our ſight. This Nature produces only in the particular focus of its volcanos, whereas every day ſhe forms other ſubſtances by the combination of glaſs with the other elements. If we would form to ourſelves a juſt idea of her formation of the globe, we muſt firſt conſider her proceſſes, which demonſtrate that it has been melted or liquified by fire; that from this immenſe heat it ſucceſſively paſſed to its actual degree; that in the firſt moments, where its ſurface begins to take conſiſtence, inequalities muſt be formed, ſuch as we ſee on the ſurface of melted matters grown cold: that the higheſt mountains, all compoſed of vitrifiable matters, which exiſt, take their date from this moment, which is alſo that of the great maſſes of air, water, and earth; that afterwards, during the long ſpace of time which the diminution of the heat of the globe to the point of actual temperature ſuppoſes, there was made in theſe mountains, which were the parts moſt expoſed to the action of external cauſes, an infinity of fuſions, ſublimations, aggregations, and transformations, by the fire of the ſun, and all the other cauſes which this great heat rendered more active than they at preſent are, and that, conſequently, we muſt refer back to this date the formation of metals and minerals which we find in great maſſes, and in thick and continued veins. The violent fire of inflamed earth, after having raiſed up and reduced into vapours all what was volatile, after having driven off from its internal parts the matters which compoſe the atmoſphere and ſea, and at the ſame time ſublimated all the leaſt fixed parts of the earth, raiſed them up, and depoſited them in every void ſpace, in all the cavities which formed on the ſurface in proportion as it cooled, this, then, is the origin and the gradation of the ſituation and formation of vitrifiable matters which fire has divided, formed, and ſublimated.

After this firſt eſtabliſhment (and which ſtill ſubſiſts) of vitrifiable matters and minerals into a great maſs, which can be attributed to the action of fire alone, water, which till then formed with air only a vaſt volume of vapours, began to take its actual ſtate ; it collected and covered the greateſt part of the ſurface of the earth, on which, finding itſelf agitated by a continual flux and reflux, by the action of winds and heat, it began to act on the works of fire : it changed, by degrees, the ſuperficies of vitrifiable matters ; it tranſported the wrecks and depoſited them in form of ſediments ; it nouriſhed ſhell-animals, it collected their ſhells, produced calcareous ſtones, formed hills and mountains, which afterwards drying received in their cavities all the mineral matters they could diſſolve or contain.

To eſtabliſh a general theory on the formation of Minerals, we muſt then begin by diſtinguiſhing firſt, thoſe which have been produced by the primitive fire of the earth while it was burning with heat ; ſecondly, thoſe which have been formed from the waſte of the firſt by the means of water ; and thirdly, thoſe which in volcanos, or other conflagrations poſterior to the primitive fire, have a ſecond time undergone the proof of a violent heat. Theſe three objects are very diſtinct, and comprehend all the mineral kingdom; by not loſing ſight of them, and by connecting each ſubſtance, we can ſcarcely be deceived in its origin, or even in the degrees of its formation. All minerals which are found in maſſes, or large veins, in our high mountains, muſt be referred to the ſublimation of primitive fire; all thoſe which are found in ſmall ramifications, in threads or in vegetations, have been formed only from the wâſte of the firſt, hurried away by the ſtillation of waters. We are evidently convinced by comparing the matter of the iron mines of Sweden with that of our own. Theſe are the immediate work of water, and we ſee them formed before our eyes; they are not attracted by the loadſtone; they do not contain any ſulphur, and are found only diſperſed in the earth; the reſt are all more or leſs ſulphureous, all attracted by the loadſtone, which alone ſuppoſes that they have undergone the action of fire; they are diſpoſed in great, hard, and ſolid maſſes: their ſubſtance is mixed with a quantity of aſbeſtos, another index of the action of fire. It is the ſame with other metals: their ancient foundation comes from fire, and all their great maſſes have been united by its action; but all their chryſtalizations, vegetations, granulations, &c. are due to the ſecondary cauſes, or to water in the greateſt part.

EXPERIMENTS ON THE PROGRESS OF HEAT IN MINERAL SUBSTANCES.

I CAUSED ten bullets to be made of forged and beaten iron; the firſt, of half-inch diameter; the ſecond, of an inch; and ſo on progreſſively to five inches: and as all the bullets were made of iron of the ſame forge, their weights were found nearly proportionable to their volumes.

The bullet of half an inch weighed 190 grains, Paris weight; that of an inch, 1522 grains; that of an inch and an half, 5136 grains; that of two inches, 12173 grains; that of two inches and an half, 23781 grains; that of three inches, 41085 grains; that of three inches and an half, 65254 grains; that of four inches, 97388 grains; that of four inches and an half, 138179 grains; and that of five inches, 190211 grains.

While theſe bullets were making, the thermometer expoſed to the open air was at the freezing point, or ſome degrees above; but in the pit where the bullets were ſuffered to cool, the thermometer was nearly ten degrees below that point; that is to ſay, to the degree of temperature of the pits of the obſervatory, and it is this degree which I have here taken for that of the actual temperature of the earth. To know the exact moment of their cooling to this actual temperature, other bullets of the ſame matters, diameters, and not heated, were made uſe of for compariſon, and which were felt at the ſame time as the others. By the immediate touch of the hand, or two hands, on the two bullets, we could judge of the moment when they were equally cold; and as the more or leſs ſmoothneſs or roughneſs on bodies makes a great difference to the touch, (a ſmooth body, whether hot or cold, appearing much more ſo than a rough body, even of the ſame matter, although they are both equally ſo) I took care that the cold bullets were rough, and like thoſe which had been heated, whoſe ſurfaces were ſprinkled over with little eminences produced by the fire.

EXPERIMENTS.

I. The bullet of half an inch was heated white in two minutes, cooled ſo as to be held in the hand in 12, and to the actual temperature in 39 minutes.

II. That of an inch, heated white in five minutes and a half, cooled ſo as to be held in the hand, in 35½ minutes, and to the actual temperature in one hour and 33 minutes.

III. That of an inch and an half, heated white in nine minutes, cooled ſo as to be held in the hand in 58 minutes, and to the actual temperature in two hours and 25 minutes.

IV. That of two inches heated white in 13 minutes, cooled ſo as to be held in the hand in one hour 20 minutes, and to the actual temperature in three hours 16 minutes.

V. That bullet of two inches and an half heated white in 16 minutes, cooled ſo as to be held in the hand in one hour 42 minutes, and to the actual temperature in four hours 30 minutes.

VI. That bullet of three inches heated white in 19½ minutes, cooled ſo as to be held in the hand in two hours ſeven minutes, and to the actual temperature in five hours eight minutes.

VII. That of three inches and an half heated white in $23\frac{1}{2}$ minutes, cooled ſo as to be held in the hand in two hours 36 minutes, and to the actual temperature in five hours 56 minutes.

VIII. That of four inches heated white in 27 minutes and an half, cooled ſo as to be held in the hand in three hours two minutes, and to the actual temperature in ſix hours 55 minutes.

IX. That of four inches and an half heated white in 31 minutes, cooled ſo as to be held in the hand in three hours and 25 minutes, and to the actual temperature in ſeven hours 46 minutes.

X. That of five inches heated white in 34 minutes, cooled ſo as to be held in the hand in three hours 52 minutes, and to the actual temperature in eight hours 42 minutes.

The moſt conſtant difference that can be taken between each of the terms which expreſs the time of cooling, from the inſtant the bullets were drawn from the fire, to that when we can touch them unhurt, is found to be about 24 minutes, for, by ſuppoſing each term to increaſe 24, we ſhall have 12, 36, 60, 84, 108, 32, 156, 180, 204, 228 minutes. And the continuation of the real times of theſe coolings are, 12, $35\frac{1}{2}$, 58, 80, 102, 127, 156, 182, 205, 232 minutes, which approach the firſt as nearly as experiment can approach calculation.

So, likewiſe, the moſt conſtant difference to be found between each of the terms of cooling to actual temperature is found to be 54 minutes, for, by ſuppoſing each term to increaſe 54, we ſhall have 39, 93, 147, 201, 255, 309, 363, 417, 471, 525 minutes; and the continuation of the real time of this cooling is found, by the preceding experiments, to be 39, 93, 145, 196, 248, 308, 356, 415, 466, 522 minutes, which approaches alſo neareſt to the firſt.

I made the like experiments upon the ſame bullets twice or thrice, but found I could only rely on the firſt, becauſe each time the bullets were heated they loſt conſiderable part of their weight, which was occaſioned not only by the falling off of the parts of the ſurface reduced into ſcoria, but alſo by a kind of drying, or internal calcination, which diminiſhes the weight of the conſtituent parts, inſomuch that it appears a ſtrong fire renders the iron ſpecifically lighter each time it is heated; and I have found, by ulterior experiments, that this diminution of weight varies much, according to the different quality of the iron. Experience has alſo confirmed me in the opinion, that the duration of heat, or the time taken up in cooling of iron, is not in a ſmaller, as ſtated in a paſſage of Newton, but in a larger ratio than that of the diameter.

Now if we would enquire how long it would require for a globe as large as the earth to cool, we ſhould find, after the preceding experiments, that inſtead of 50,000 years, which Newton aſſigns for the earth to cool to the actual temperature, it would take 42,964 years, 221 days, to cool only to the point where it would ceaſe to burn, and 86,667 years and 132 days, to cool to the actual temperature.

It might only be ſuppoſed, that the refrigeration of the earth ſhould be conſiderably increaſed, becauſe we imagine that refrigeration is only performed by the contact of the air, and that there is a great difference between the time of refrigeration in the air and in vacuo; and ſuppoſing that the earth and air cool in the ſame time in vacuo, this ſurplus of time ſhould be reckoned. But, in fact, this difference of time is very inconſiderable, for though the denſity of the medium, in which a body cools, makes ſomething on the duration of the refrigeration, this effect is much leſs than might be imagined, ſince in mercury, which is ten thouſand times denſer than air, it is only requiſite to plunge bodies therein about nine times as often as is required to produce the ſame refrigeration in air. The principal cauſe of refrigeration is not, therefore, the contact of the ambient medium, but the expanſive force which animates the parts of heat and fire, drive them out of the bodies wherein they reſide, and impels them directly from the centre to the circumference.

By comparing the time employed in the preceding experiments to heat iron globes, with that requiſite to cool them, we find that they may be heated till they become white in one ſixth part of the time they take to cool, ſo as to be held in the hand, and about one eighteenth of that to cool to actual temperature, ſo that there is a great error in the eſtimate Newton made on the heat communicated by the ſun to the comet of 1680, for that comet having been expoſed to the violent heat of the ſun but a ſhort time could receive it only in proportion thereto, and not in ſo great a degree as that author ſuppoſes. Indeed, in the paſſage alluded to, he conſiders the heat of red-hot iron much leſs than in fact it is, and that he himſelf ſtates it to be, in a Memoir, entitled, *The Scale of Heat*, publiſhed in the Philoſophical Tranſactions of 1701, which was many years before the publication of his *principles.*

We ſee in that excellent Memoir, which includes the germ of all the ideas on which thermometers have ſince been conſtructed; that Newton, after very exact experiments, makes the heat of boiling water to be three times greater than that of the ſun in the height of ſummer; that of melted tin, ſix times greater; that of melted lead, eight times; that of melted regulus, twelve times; and that of a common culinary fire, ſixteen or ſeventeen times; from hence we may conclude, that the heat of iron, when heated ſo as to become white, is ſtill much greater, ſince it requires a fire continually animated by the bellows to heat it to that degree. Newton ſeems to be ſenſible of this, for he ſays, that the heat of iron in that ſtate appears to be ſeven or eight times greater than that of boiling water. This diminiſhes half the heat of this comet, compared to that of hot iron.

But this diminution, which is only relative, is nothing in compariſon with that real and very great diminution which reſults from our firſt conſideration. For the comet to have received this heat a thouſand times greater than that of red-hot iron, it would require to have remained for a very long time in the vicinity of the ſun, whereas it only paſſed very rapidly at a ſmall diſtance. It was on the 8th of December, 1680, at $\frac{6}{1000}$ diſtance from the earth to the centre of the ſun; but 24 hours before, and as many after, it was at a diſtance ſix times greater, and where the heat was conſequently 36 times leſs.

To know the quantity of this heat communicated to the comet by the ſun, we here find how we ſhould make this eſtimation tolerably juſt, and, at the ſame time, make the compariſon with hot iron by the means of my experiments.

We ſhall ſuppoſe, as a fact, that this comet took up 666 hours to deſcend from the point where it then was, and which point was at an equal diſtance as the earth is from the ſun, conſequently it received an equal heat to what the earth receives from that luminary, and which I here take for unity; we ſhall likewiſe ſuppoſe that the comet took 666 hours more to aſcend from the loweſt point of its perihelium to this ſame diſtance; and ſuppoſing alſo its motion uniform, we ſhall perceive, that the comet being at the loweſt point of its perihelium, that is, to $\frac{6}{1000}$ of the diſtance from the earth to the ſun, the heat it received in that motion was 2,700,766 times greater than that the earth receives. By giving to this motion a duration of 80 minutes, to wit, 40 for its deſcent, and 40 for its aſcent, we ſhall have, at 6 diſtance, 27,776 heat during 80 minutes, at 7 diſtance 20,408 heat alſo during 80 minutes, at 8 diſtance 15,625 heat during 80 minutes, and thus, ſucceſſively, to the diſtance of a 1000, where the heat is 1. By ſumming up the heats at each diſtance we ſhall find 363,410 to be the total of the heat the comet has received from the ſun, as much in deſcending as in aſcending, which muſt be multiplied by the time, that is, by four thirds of an hour, we ſhall then have 484,547, which divided by 2,000 repreſents the ſolid heat the earth received in this time of 1332 hours, ſince the diſtance is always 1,000, and the heat always equals 1. Thus we ſhall have 242,$\frac{547}{2000}$ for the heat the comet received more than the earth during the whole time of its perihelium inſtead of 28,000, as Newton ſuppoſed it, becauſe he took only the extreme point, and paid no attention to the very ſmall duration of time. And ſtill this heat muſt be diminiſhed 242,$\frac{547}{2000}$, becauſe the comet ran, by its acceleration, as much more way in the ſame time as it was nearer the ſun. But by neglecting this diminution, and only admitting that the comet received an heat nearly 242 times greater than that of our ſummer's ſun, and, conſequently, 17$\frac{7}{8}$ times greater than that of hot iron, according to Newton's eſtimation, or only ten times greater according to this eſtimation; it muſt be ſuppoſed, that to give a heat ten times greater than that of red hot iron, it required ten times more time; that is to ſay, 1332; conſequently, we may compare the comet to a globe of iron heated by a forge fire for 13320 hours, to heat it to a whiteneſs.

Now we find by calculation on my experiments, that with a forge fire, we can heat to a whiteneſs a globe whoſe diameter is 228342½ inches in 799200 minutes, and, conſequently, the whole maſs of the comet to be heated to the point of iron to a whiteneſs, during the ſhort time it was expoſed to the heat of the ſun, could only be 223342½ inches in diameter; and even then it muſt have been ſtruck on all ſides, and at the ſame time, by the light of the ſun. Thus comets, when they approach the ſun, do not receive an immenſe nor a very durable heat, as Newton ſays, and as we at the firſt view might be inclined to believe. Their ſtay is ſo ſhort in the vicinity of the ſun, that their maſſes have not time to be heated, and beſides only part of their ſurface is expoſed thereto; this part is burnt by the extreme heat, which by calcining and volatilizing the matter of this ſurface, drives it outwardly in vapours and duſt from the oppoſite ſide to the ſun; and what is called the tail of the comet, is nothing elſe than the light of the ſun rendered ſenſible, as in a dark room, by thoſe atoms which the heat lengthens as it is more violent.

But another different and more important conſideration is, that to apply the reſult of our experiments and calculation to the comet and earth, we muſt ſuppoſe them compoſed of matters which would demand as much time as iron to cool: whereas, in reality, the principal matters of which the terreſtrial globe is compoſed, ſuch as clay, gres, ſtones, &c. cannot poſſibly take ſo long.

To ſatisfy myſelf on this point, I cauſed globes of clay and marl to be made, and having heated them at the ſame forge until white, I found that the clay balls of two inches, cooled in 38 minutes ſo as to be held in the hand; thoſe of two inches and an half, in 48 minutes; and thoſe of three inches, in 60 minutes; which being compared with the time of the refrigeration of iron bullets of the ſame diameters, give 38 to 80 for two inches, 48 to 102 for two inches and an half, and 60 to 127 for three inches; ſo that only half the time is required for the refrigeration of clay, to what is neceſſary for iron.

I found alſo, that lumps of clay, or marl, of two inches, refrigerated ſo as to hold them in the hand in 45 minutes; thoſe of two inches and an half in 58; and thoſe of three inches in 75, which being compared with the time of refrigeration of iron bullets of the ſame diameters, gives 46 to 80 for two inches, 58 to 102 for two inches and an half, and 75 to 127 for three inches, which nearly form the ratio of 9 to 5; ſo that for the refrigeration of clay, more than half the time is required than for iron.

It is neceſſary to obſerve, that globes of clay heated white, loſt more of their weight than iron bullets, even to the ninth or tenth part of their weight: whereas gres heated in the ſame fire, loſt ſcarcely any thing, although the whole ſurface was covered over with ſcales, and reduced into glaſs. As this appeared ſingular, I repeated the experiments ſeveral times, increaſing the fire, and continuing it longer than for iron; and although it ſcarcely required a third of the time to redden clay, to what it did to redden iron, I kept them in the fire thrice as long as was requiſite, to ſee if they would loſe more, but I found very trifling diminutions; for the globe of two inches heated for eight minutes, which weighed ſeven ounces, two drachms, and thirty grains, before it was put in the fire, loſt only forty-one grains, which does not make a hundredth part of its weight; and that of three inches, which weighed twenty-four ounces, five drachms, and thirteen grains, having been heated by the fire for eighteen minutes, that is nearly as much as iron, loſt only ſeventy-eight grains, which does not make the hundredth and eighty-firſt part of its weight. Theſe loſſes are ſo trifling, that it may be looked upon, in general, as certain that pure clay loſes nothing of its weight in the fire, for thoſe trifling diminutions were certainly occaſioned by the ferruginous parts which were found in the clay, and were in part deſtroyed by the fire. It is alſo worthy obſervation, that the duration of heat in different matters expoſed to the ſame fire for an equal time, is always in the ſame proportion, whether the degree of heat is greater or ſmaller.

I have made ſimilar experiments to the preceding on marble, ſtone, lead, and tin, by a heat only ſtrong enough to melt tin, and I found, that iron refrigerated in eighteen minutes, marble refrigerated to the ſame degree in twelve minutes, ſtone in eleven, lead in nine, and tin in eight. It is not, therefore, in proportion to their denſity, as is commonly ſuppoſed, that bodies receive more or leſs heat, but in an inverted ratio of their ſolidity ; that is, of their greater or leſſer *non fluidity* ; ſo that, by the ſame heat, leſs time is requiſite to heat or cool the moſt denſe fluid.

To prevent the ſuſpicion of vainly dwelling upon aſſertion, I think it neceſſary to remark upon what foundation I build this theory ; I have found that bodies which ſhould heat in ratio of their diameters, could be only thoſe which might be perfectly permeable to heat, and as would heat or cool in the ſame time ; from hence, I concluded that fluids, whoſe parts are only held together by a ſlight connection, might approach nearer this perfect permeability than ſolids, whoſe parts have more coheſion. In conſequence of this, I made experiments, by which I found, that with the ſame heat all fluids, however denſe, heat and cool more readily than any ſolids, however light, ſo that mercury, for example, heats much more readily than wood, although it be fifteen or ſixteen times more denſe.

This made me perceive that the progreſs of heat in bodies muſt not, in any caſe, be made relatively to their denſity; and I have found by experience, that this progreſs, as well in ſolids as fluids, is made rather by reaſon of their fluidity, or in an inverted ratio of their ſolidity. I mean by *ſolidity* the quality oppoſite to fluidity; and I ſay, that it is in an inverted ratio of this quality that the progreſs of heat is made in moſt bodies; and that they heat or cool ſo much the faſter as they are the more fluid, and ſo much the ſlower as they are more ſolid, every other circumſtance being equal.

To prove that ſolidity, taken in this ſenſe, is perfectly independent of denſity, the moſt or leaſt denſe matters, heat or cool more readily than other more or leſs denſe matters, for example, gold or lead, which are much more denſe than iron and copper, heat and cool much quicker; while tin and marble, which are not ſo denſe, heat and cool much faſter than iron and copper; and there are likewiſe many other matters which come under the ſame deſcription; ſo that denſity is no ways relative to the ſcale of the progreſs of heat in ſolid bodies.

It is likewiſe the ſame in fluids, for I have obſerved, that quickſilver, which is thirteen or fourteen times more denſe than water, nevertheleſs heats and cools in leſs time than water;

and ſpirit of wine, which is leſs denſe than water, heats and cools much quicker; ſo that generally the progreſs of heat in bodies, as well for the ingreſs as egreſs, has an affinity with their denſity, and is principally made in ratio of their fluidity, by extending the fluidity to a ſolid; from hence I concluded, that we ſhould know the real degree of fluidity in bodies, by heating them to the ſame heat; for their fluidity would be in a like ratio as that of the time during which they would receive and loſe this heat; and that it would be the ſame with ſolid bodies. They will be ſo much the more ſolid, that is to ſay, ſo much the more *non fluids*, as they require more time to receive and loſe this heat, and that almoſt generally to what I preſume; for I have already tried theſe experiments on a great number of different matters, and from them I made a table, which I have endeavoured to render as complete and exact as poſſible.

We cauſed ſeveral globes to be made of an inch diameter from the following matters, which nearly repreſent the Mineral kingdom.

M. Tillet, of the Academy of Sciences, made the globe of refined gold at my particular requeſt, and the whole of them weighed as follows:

	oz.	d.	gr.
Gold	6	2	17
Lead	3	6	28
Pure ſilver	3	3	22
Biſmuth	3	0	3
Copper-red	2	7	56
Iron	2	5	10
Tin	2	3	48
Antimony melted, and which had ſmall cavities on its ſurface	2	1	34
Fine	2	1	2
Emery	1	2	24½
White marble	1	0	25
Pure clay	0	7	24
Marble common of Montbard	0	7	20
White gypſum, improperly called Alabaſter	0	6	36
Calcareous white ſtone of the quarry of Anieres, near Dijon	6	6	6
Rock chryſtal; it was a little too ſmall, and had many defects. I preſume that without them it would have weighed	0	6	22
Common glaſs	0	6	21

Pure

	oz.	d.	gr.
Pure earth, very dry	0	6	16
Oker	0	5	9
Porcelain of the Court de Lauraguais	0	5	2½
White chalk	0	4	49
Cherrywood, which although lighter than moſt other woods, is that which takes in the leaſt fire	0	1	59

I muſt here obſerve, that a poſitive concluſion muſt not be made of the exact ſpecific weight of each matter from the preceding table, for notwithſtanding the precaution that was taken to render the globes equal, as I was obliged to employ different workmen, ſome were too large, and others too ſmall. Thoſe which were more than an inch diameter were diminiſhed, but thoſe of rock chryſtal, glaſs and porcelain, which were rather too ſmall, we ſuffered to remain, and only rejected thoſe of agate, jaſper, and porphyry, which were ſenſibly ſo. This preciſion in ſize was not abſolutely neceſſary, for it could very little alter the reſult of my experiments.

Previous to ordering theſe globes, I expoſed to a like degree of fire, a ſquare maſs of iron, and another of lead of two inches diameter, and found, by reiterated eſſays, that lead heated and cooled in much leſs time than iron. I made the ſame experiment on red copper, and that required more time to heat and cool than lead, and leſs than iron. So that of theſe three matters, iron appeared the leaſt acceſſible to heat, and, at the ſame time, that which retained it the longeſt. From which I learn that the law of the progreſs of heat in bodies was not proportionable to their denſity, ſince lead, which is more denſe than iron or copper, nevertheleſs heats and cools in leſs time than either. As this object appeared important, I was induced to have theſe globes made, and to be more perfectly ſatisfied of the progreſs of heat in a great number of different matters, I always placed the globes at an inch diſtance from each other, before the ſame fire, or in the ſame oven, 2, 3, 4, or 5, together with a globe of tin in the midſt of them. In moſt of my experiments I ſuffered them to be expoſed to the ſame active fire till the globe of tin began to melt, and at that inſtant they were all removed, and placed on a table in ſmall caſes. I ſuffered them to cool without moving, often trying whether I could touch them, and the moment they left off burning, and I could hold them in my hands half a ſecond, I marked the time which had paſſed ſince I drew them from the fire. I afterwards ſuffered them to cool to the actual temperature, of which I endeavoured to judge by means of touching other ſmall globes of the ſame matters that had not been heated. Of all the matters which I put to the trial, there was only ſulphur which melted in a leſs degree of heat than tin, and notwithſtanding its diſagreeable ſmell I ſhould have taken it for a term of compariſon, but being a brittle matter which diminiſhes by friction, I preferred tin, although it required nearly double the heat to melt.

Having heated the bullets of iron, copper, lead, tin, gres, and Montbard marble, together in the ſame fire, and for an equal length of time they cooled in the following order:

So as to be held in the hand for half a ſecond.		*To actual temperature.*	
	Min.		Min.
Tin in - - -	6½	In - - - - -	16
Lead in - - -	8	In - - - - -	17
Gres in - - -	9	In - - - - -	19
Common marble in	10	In - - - - -	21
Copper in -	11½	In - - - - -	30
Iron in - -	13	In - - - - -	38

By a ſecond experiment with a fiercer fire, ſufficient to melt the tin bullet, the five others cooled,

So as to be held in the hand.		*To actual temperature.*	
	Min.		Min.
Lead in - -	10½	In - - -	42
Gres in - -	12½	In - - - -	46
Common marble	13½	In - - - -	50
Copper - -	19½	In - - - -	51
Iron - - -	23½	In - - - -	54

By a third experiment, with a leſs degree of fire than the preceding, the ſame bullets with a freſh tin bullet, cooled in the following order:

So as to be held in the hand.		*To actual temperature.*	
	Min.		Min.
Tin in - - -	7½	In - - - -	25
Lead in - -	9½	In - - - -	25
Gres in - -	10½	In - - - -	37
Common marble	12	In - - - -	39
Copper - -	14	In - - - -	44
Iron - - -	17	In - - - -	50

From theſe experiments, which I made with as much preciſion as poſſible, we may conclude, firſt, that the time of refrigeration of iron, ſo as to be held in the hand, is to that of copper : : 53½ : 45, and to the point of temperature : : 142 : 125.

2dly, That the time of refrigeration of iron, ſo as to be held in the hand, is to that of the firſt refrigeration of common marble : : 53½ : 35½ and their entire refrigeration : : 142 : 110.

3dly, That the time of refrigeration of iron, to that of gres, ſo as to be held in the hand, is : : 53½ : 32 and : : 142 : 102½, for their entire refrigeration.

4thly, That the time of refrigeration of iron to that of lead, ſo as to be held in the hand, is : : 53½ : 27 and 142 : 94½ for their entire refrigeration.

In an oven hot enough to melt tin, although all the coals and cinders were drawn out, I placed, on a piece of iron wire, five bullets, diſtant from one another about nine lines, after which the oven was ſhut, and having drawn them out, in about 18 minutes they cooled,

So as to be held in the hand.		*To actual temperature.*	
	Min.		Min.
Melted tin in -	8	In - - - -	24
Silver in - -	14	In - - - -	40
Gold in - -	15	In - - - -	46
Copper in -	16½	In - - - -	50
Iron in - -	18	In - - - -	56

In the ſame oven, but with a ſlower heat, the ſame bullets, with another bullet of tin, cooled,

So as to be held in the hand.		*To actual temperature.*	
	Min.		Min.
Tin in - -	7	In - - - -	20
Silver in - -	11	In - - - -	31

Gold in	12½	In	40
Copper in	14	In	43
Iron in	16½	In	47

In the ſame oven, but with a ſtill leſs degree of heat, the ſame bullets cooled,

So as to be held in the hand.	Min.	*To actual temperature.*	Min.
Tin in	6	In	17
Silver in	9	In	26
Gold in	9½	In	28
Copper in	10	In	31
Iron in	11	In	35

Having placed in the ſame oven five other bullets, their refrigeration was in the following proportions.

So as to be held in the hand.	Min.	*To actual temperature.*	Min.
Antimony in	6½	In	25
Biſmuth in	7	In	26
Lead in	8	In	27
Zinc in	10½	In	30
Emery in	11½	In	38

In the ſame oven, and in the ſame manner, another bullet of Biſmuth was placed, with ſix other bullets, which cooled,

So as to be held in the hand.	Min.	*To actual temperature.*	Min.
Antimony in	6	In	23
Biſmuth in	6	In	25

Lead

Lead in	7½	In	28
Silver in	9½	In	30
Zinc in	10½	In	32
Gold in	11½	In	34
Emery in	13½	In	39

There was put in the ſame oven a bullet of glaſs, another of tin, one of copper, and one of iron, and they cooled,

	So as to be held in the hand.		*To actual temperature.*
	Min.		Min
Tin in	8	In	27
Glaſs in	8½	In	22
Copper in	14	In	42
Iron in	16	In	50

Bullets of gold, glaſs, porcelain, gypſum, and gres, were heated together, and cooled,

	So as to be held in the hand.		*To actual temperature.*
	Min.		Min.
Gypſum in	8	In	24
Porcelain in	8½	In	25
Glaſs in	2	In	26
Gres in	10	In	32
Gold in	14½	In	45

Bullets of ſilver, common marble, hard ſtone, white marble, and ſoft calcareous ſtone of Amiens, near Dijon, were heated like the former, and cooled,

So

So as to be held in the hand.	Min.	*To actual temperature.*	Min.
Soft calcareous ſtone in	8	In - -	25
Hard ſtone in -	10	In - -	34
Common marble in	11	In - -	35
White marble in -	12	In - -	36
Silver in - -	13½	In - -	40

The whole of theſe experiments were made with the utmoſt care and attention, not only by myſelf but in the preſence of ſeveral perſons, who alſo endeavoured to judge of the firſt degree of temperature by holding the bullets for half a ſecond in their hands, and the relations of which are more exact than thoſe of the actual temperature, becauſe that being variable the reſult muſt ſometimes vary alſo.

With a view to avoid that prolixity which would neceſſarily attend the continual repetition in a comparative ſtatement of the refrigeration of theſe different bodies, we have connected them in a general table, and taking 10,000 for the ſtandard of compariſon, their differences may be ſeen at one view.

A TABLE

OF THE

Relations of different Mineral Subſtances.

IRON, with

		Firſt Refrig.	Entire Refrig.
Emery - -	10000 to	9117	9020
Copper - -	—— to	8512	8702
Gold - -	—— to	8160	8148
Zinc - -	—— to	7654 6804	6020
Silver - - -	—— to	7619	7423
Marble White -	—— to	6774	6704
Marble common -	—— to	6636	6746
Stone calcareous hard -	—— to	6617	6274
Gres - -	—— to	5796	6926
Glaſs - -	—— to	5576	5805
Lead - -	—— to	5143	6482
Tin - -	—— to	4898	4921
Stone calcareous ſoft -	—— to	4194	4659
Clay - -	—— to	4198	4490
Biſmuth - -	—— to	3580	4081
Chalk - -	—— to	3086	3878
Gum - -	—— to	2325	2817
Wood - -	—— to	1890	1594
Pumice-ſtone -	—— to	1627	1268

EMERY,

EMERY, with

		Firſt Refrig.	Entire Refrig.
Copper	10000 to	8519	8148
Gold	—— to	8513	8560
Zinc	—— to	8390	7693
		7458	
Silver	—— to	7778	7895
Stone calcareous hard	—— to	7304	6963
Gres	—— to	6552	6517
Glaſs	—— to	5862	5506
Lead	—— to	5718	6643
Zinc	—— to	5658	6000
Clay	—— to	5185	5185
Biſmuth	—— to	4949	6060
Antimony	—— to	4540	5827
Oker	—— to	4259	3827
Chalk	—— to	3684	4105
Gypſum	—— to	2368	2947
Wood	—— to	1552	3146

COPPER, with

Gold	10000 to	9136	9194
Zinc	—— to	8571	9250
		7619	
Silver	—— to	8395	7823
Marble common	—— to	7639	8019
Gres	—— to	7333	8160
Glaſs	—— to	6667	6567
Lead	—— to	6179	7367

Tin

		Firſt Refrig.	Entire Refrig.
Tin	10000 to	5746	6916
Stone calcareous tender	—— to	5168	5633
Clay	—— to	5652	6363
Biſmuth	—— to	5686	5959
Antimony	—— to	5130	5808
Oker	—— to	5003	4697
Chalk	—— to	4068	4368

GOLD, with

Zinc	10000 to	2474 8422	9304
Silver	—— to	8936	8686
Marble white	—— to	8101	7863
Marble common	—— to	7342	7434
Stone calcareous hard	—— to	7383	7516
Gres	—— to	7368	7627
Glaſs	—— to	7103	5232
Lead	—— to	6526	7500
Tin	—— to	6324	6051
Stone calcareous ſoft	—— to	6087	5811
Clay	—— to	5814	5077
Biſmuth	—— to	5658	7043
Porcelain	—— to	5526	5593
Antimony	—— to	5395	6348
Oker	—— to	5349	4462
Chalk	—— to	4571	4452
Gypſum	—— to	2989	3293

ZINC, with

		Firſt Refrig.	Entire Refrig.	
Silver	10000 to	8904	8990	10015
Marble white	—— to	8305	8424	7194
Gres	—— to	6242	7333	5838
Lead	—— to	6051	7947	4950
Tin	—— to	6777	6240	5666
Stone calcareous ſoft	—— to	5536	7719	4425
Clay	—— to	5484	7458	4573
Biſmuth	—— to	5343	7547	4232
Antimony	—— to	5246	6668	4135
Chalk	—— to	3729	5862	2618
Gypſum	—— to	3409	4261	2298

SILVER, with

Marble white	10000 to	8681	9200
Marble common	—— to	7912	9040
Stone calcareous hard	—— to	7436	8580
Gres	—— to	7361	7767

Glaſs

		Firſt Refrig.	Entire Refrig.
Glaſs	10000 to	7230	7212
Lead	—— to	7154	9184
Tin	—— to	6176	6289
Stone calcareous ſoft	—— to	6178	6289
Clay	—— to	6034	6710
Biſmuth	—— to	6308	8877
Porcelain	—— to	5556	5242
Antimony	—— to	5692	7653
Oker	—— to	5000	5668
Chalk	—— to	4310	5000
Gypſum	—— to	2879	3366
Wood	—— to	2253	1864
Pumice-ſtone	—— to	2059	1525

WHITE MARBLE, with

Marble common	10000 to	8992	9405
Stone hard	—— to	8594	9130
Gres	—— to	8286	8990
Lead	—— to	7604	5555
Tin	—— to	7143	6792
Stone calcareous ſoft	—— to	6792	7281
Clay	—— to	6400	6286
Antimony	—— to	6286	6792
Oker	—— to	5400	5571
Gypſum	—— to	4920	5116
Wood	—— to	2200	2857

COMMON MARBLE, with

		Firſt Refrig.	Entire Refrig.
Stone hard	10000 to	9483—	9665
Gres	—— to	8767—	9273
Lead	—— to	7671—	8590
Tin	—— to	7424—	6666
Stone ſoft	—— to	7327—	7959
Clay	—— to	7272—	7213
Antimony	—— to	6279—	8333
Oker	—— to	6136—	6393
Chalk	—— to	5581—	6333
Wood	—— to	2500—	3279

HARD CALCAREOUS STONE, with

Gres	10000 to	9268—	9355
Glaſs	—— to	8710—	8352
Lead	—— to	8571—	7931
Tin	—— to	1095—	7931
Stone ſoft	—— to	8000—	8095
Clay	—— to	6190—	6897
Oker	—— to	4762—	5517
Wood	—— to	2195—	4516

GRES, with

Glaſs	10000 to	9324—	7939
Lead	—— to	8561—	8950
Tin	—— to	7667—	7633
Stone ſoft	—— to	7644—	7193
Porcelain	—— to	7364—	7059

Antimony

		Firſt Refrig.	Entire Refrig.
Antimony	10000 to	7333	6170
Gypſum	—— to	4568	5000
Wood	—— to	2368	4828

GLASS, with

Lead	10000 to	9318	8548
Tin	—— to	9107	8679
Clay	—— to	7938	7643
Porcelain	—— to	7692	8863
Oker	—— to	6289	6500
Chalk	—— to	6104	6195
Gypſum	—— to	4160	6011
Wood	—— to	2647	5514

LEAD, with

Tin	10000 to	8695	8333
Stone ſoft	—— to	8437	7192
Clay	—— to	7878	8536
Biſmuth	—— to	8698	8750
Antimony	—— to	8241	8201
Oker	—— to	6060	7073
Chalk	—— to	5714	6111
Gypſum	—— to	4736	5714

TIN, with

Clay	10000 to	8823	9524
Biſmuth	—— to	8889	9400
Antimony	—— to	8710	9156
Oker	—— to	5882	7619

		Firſt Refrig.	Entire Refrig.
Chalk	10000 to	6394	6842
Gypſum	—— to	4090	4912

STONE CALCAREOUS SOFT, with

Antimony	10000 to	7742	9542
Chalk	—— to	7288	7312
Gypſum	—— to	4182	5211

CLAY, with

Biſmuth	10000 to	8870	9416
Oker	—— to	8400	8571
Chalk	—— to	7701	8000
Gypſum	—— to	5185	8055
Wood	—— to	3437	4545

BISMUTH, with

Antimony	10000 to	9349	9572
Oker	—— to	8846	7380
Chalk	—— to	8020	9500

PORCELAIN, with

Gypſum	10000 to	5301	6500

ANTIMONY, with

Chalk	10000 to	8431	7391
Gypſum	—— to	3833	5476

OKER, with

Chalk	10000 to	8954	8889
Gypſum	—— to	6364	9062
Wood	—— to	4074	5128

CHALK,

		Firſt Refrig.	Entire Refrig.
CHALK, with			
Gypſum - -	10000 to	6667	7920
GYPSUM, with			
Wood - -	10000 to	8000	5260
Pumice-ſtone - -	10000 to	7009	4560
WOOD, with			
Pumice-ſtone -	10000 to	8750	8182

Notwithſtanding the aſſiduity I uſed in my experiments, and the care I took to render the relations exact, I own there are ſtill ſome imperfections in the foregoing table, but the defects are trivial, and do not much influence the general reſults; for example, we ſhall eaſily perceive, that the relation of zinc to lead being 10,0000 to 6,051, that of zinc to tin ſhould be leſs than 6,000, whereas it is found 6,777 in the table. It is the ſame with reſpect of ſilver to biſmuth, which ought to be leſs than 6,308, and alſo with regard of lead to clay, which ought to be more than 8,000, but in the table is only 7,878. This difference proceeded from the leaden and biſmuth bullets not being always the ſame; they melted, as well as thoſe of tin and antimony, and, therefore, could not fail of producing variations, the greateſt of which are the three I have juſt remarked. It was not poſſible for me to do better ; the different bullets of lead, tin, biſmuth, and antimony, which I ſucceſſively made uſe of, were made in the ſame manner, but the matter of each might be ſomewhat different, according to the quantity of the alloy in the lead and tin, for I had only pure tin for the two firſt bullets ; beſides, there remains very often a ſmall cavity in the melted bullet, and theſe little cauſes are ſufficient to produce the little differences which may be remarked in the table.

On the whole, to draw from theſe experiments all the profit that can be expected, the matters which compoſe the object muſt be divided into four claſſes, viz. 1. Metals. 2. Semi-metals and Metallic Minerals. 3. Vitreous and Vitreſcible Subſtances. And 4. Calcareous and Calcinable Subſtances. Afterwards the matters of each claſs muſt be compared between themſelves to diſcover the cauſe, or cauſes, of the order which follows the progreſs of heat in each, and then with each other, in order to deduce ſome general reſults.

Firſt. The order of the ſix metals, according to their *denſity*, is tin, iron, copper, ſilver, lead, and gold ; whereas the order in which they receive and loſe their heat is tin, lead, ſilver, gold, copper, and iron; ſo that in tin alone retains its place.

The progreſs and duration of heat in metals does not then follow the order of their denſity, except in tin, which, being the leaſt denſe, is alſo that which ſooneſt loſes its heat; but the order of the five other metals demonſtrates that it is in relation to their fuſibility that all receive and loſe heat; for iron is more difficult to melt than gold, gold more than ſilver, ſilver more than lead, and lead more than tin. Nevertheleſs, it would be advancing too much to pretend that we muſt attribute to all fuſibility, and nothing to denſity. Nature never deprives herſelf of one of her properties in favour of another in an abſolute manner; that is to ſay, in a mode that the firſt has not any influence on the ſecond. Thus, denſity may be of ſome weight in the progreſs of heat; but we may ſafely affirm, that in the ſix metals it has very little comparatively with fuſibility.

This fact was neither known to chemiſts nor phyſicians; they did not even imagine that gold, which is more than twice as denſe as iron, nevertheleſs loſes its heat near a third ſooner. It is the ſame with lead, ſilver, and copper, which are all more denſe than iron, and which, like gold, heat and cool more readily; for, although the refrigeration has been queſtioned, experiments demonſtrate that there is an ingreſs of heat into bodies as well as an egreſs, and that thoſe which receive it the quickeſt, are alſo thoſe which loſe it the ſooneſt.

If we reflect on the real principles of denſity, and the cauſe of fuſibility, we ſhall perceive, that denſity depends abſolutely on the quantity of matter which Nature places in a given ſpace; that the more ſhe can make it enter therein, the more denſity there will be, and that gold, in this reſpect, is of all ſubſtances, that which contains the moſt matter relatively to its volume. It is for this reaſon that it has been hitherto thought, that more time is required to heat or cool gold than other metals; and it was natural enough to ſuppoſe, that containing double or treble the matter in the ſame volume, double or treble time would be required to penetrate it with heat; nay this would be true, if in every ſubſtance the conſtituent parts were of the ſame figure and ranged the ſame. But in the moſt denſe, the molecules of matter are, probably, of a figure ſufficiently regular not to leave very void places between them; in others which are not ſo denſe, and their figures more irregular, more vacuities are left, and in the lighteſt, the molecules being few, and moſt likely of a very irregular figure, a thouſand times more void is found than plenitude; for it may be demonſtrated by other experiments, that the volume of even the moſt denſe ſubſtance contains more void ſpace than full matter.

Now, the principal cauſe of fuſibility is the facility the particles of heat find in ſeparating theſe molecules of full matter from each other; let the ſum of the vacuities be greater or leſs, which cauſes denſity or lightneſs, it is indifferent to the ſeparation of the molecules which conſtitute the plenitude; and the greater or leſs fuſibility depends entirely on the power of coherence which retains the maſſive parts united, and oppoſe themſelves more or leſs to their ſeparation. The dilatation of the total volume is the firſt degree of the action of heat; and in different metals it is made in the ſame order as the fuſion of the maſs, which is performed by a greater degree of heat or fire. Tin, which melts the moſt ready, is alſo that which dilates the quickeſt; and iron, which is the moſt difficult to melt, is likewiſe that whoſe dilatation is the ſloweſt.

After theſe general poſitions, which appear clear, preciſe, and are founded on experiments that nothing can contradict, it might be imagined that ductility would follow the order of fuſibility, becauſe the more or leſs ductility ſeems to depend on the greater or leſs adheſion of the parts in each metal; nevertheleſs, ductility ſeems to have as much connection with the order of denſity, as with that of their fuſibility; I ſhould readily ſay, it is in a ratio compoſed of the two others, but that would be only by eſtimation, and a preſumption which is, perhaps, not founded; for it is not ſo eaſy to exactly determine the different degrees of fuſibility, as thoſe of denſity; and as ductility participates of both, and varies according to circumſtances, we have not as yet acquired the neceſſary knowledge to pronounce affirmatively on this ſubject, though it is moſt certainly of ſufficient importance to merit particular reſearches. The ſame metal when cold gives quite different reſults of what follows an experiment when hot, although treated in the ſame manner. Malleability is the firſt mark of ductility; but that gives only one imperfect idea of the point to which ductility may extend; nor can ſimple lead, the moſt malleable metal, be drawn into ſuch fine threads as gold, or even as iron, which is the leaſt malleable. Beſides, we muſt aſſiſt the ductility of metals with the addition of fire, without which they become brittle: even iron, although the moſt robuſt, is brittle like the reſt. Thus the ductility of one metal, and the extent of continuity which may ſupport it, depends not only on its denſity and fuſibility, but alſo on the manner and ſpace in which it is heated, and of the addition of heat or fire which is properly given to it.

II. By comparing thoſe ſubſtances we term *ſemi-metals* and *metallic minerals*, which want ductility, we ſhall perceive, that the order of their denſity is emery, zinc, antimony, and biſmuth, and that in which they receive and loſe heat, is antimony, biſmuth, zinc, and emery; and which does not in any meaſure follow the order of their denſity, but rather that of their fuſibility. Emery, which is a ferruginous mineral, although as denſe again as biſmuth, retains heat longer. Zinc, which is lighter than antimony or biſmuth, retains heat longer than either. Antimony and biſmuth, receive and keep it nearly alike. There is, therefore, ſemi-metals, and metallic minerals, which, like metals, receive and loſe heat nearly in the ſame relation as that of their fuſibility, and partake very little of their denſity.

But by joining the ſix metals, and the four ſemi-metals, or metallic minerals, which I have tried, we ſhall find the order of the denſities of theſe ten mineral ſubſtances to be tin, emery, zinc, antimony, iron, copper, biſmuth, ſilver, lead, and gold. And that the order in which theſe ſubſtances heat and cool, is antimony, biſmuth, tin, lead, ſilver, zinc, gold, copper, emery, and iron, in which there are two things that do not appear to perfectly agree with the order of fuſibility.

Firſt, Antimony, which, according to Newton, ſhould heat and cool ſlower than lead, ſince by his experiments it requires ten degrees of the ſame heat to fuſe, while eight is ſufficient for lead; whereas by my experiments antimony is found to heat and cool quicker than lead. But it ſhould be obſerved that Newton made uſe of the regulus of antimony, and that I employed only melted antimony in my experiments. Now this regulus of antimony, or native antimony, is much more difficult to fuſe than antimony which has already undergone a firſt fuſion, therefore that does not make an exception to the rule. On the whole, I do not know what relation native antimony, or regulus of antimony, may have with the other matters I have heated and cooled; but I preſume, after the experiments of Newton, that it heats and cools ſlower than lead.

Secondly, it is pretended, that zinc fuſes more eaſily than ſilver, conſequently it ſhould be found before ſilver in the order indicated by my experiments, if this order was in all caſes relative to that of fuſibility; and I own that this ſemi-metal ſeems, at the firſt glance, to make an exception to the law which is followed by all the others; but it muſt be obſerved, that the difference given by my experiments between zinc and ſilver is very trifling. The ſmall globe of ſilver which I made uſe of was of the pureſt ſilver, without the leaſt mixture of copper; but I had my doubts whether that of zinc was entirely free from fuſible matters, and, therefore, after all my experiments, I returned the globe of zinc to M. Rouelle, a celebrated profeſſor of chemiſtry, requeſting him carefully to examine it, which having done, after ſeveral trials he found a pretty conſiderable quantity of this iron, or ſaffron of ſteel, therein.

I have, therefore, had the ſatisfaction to ſee that not only my ſuppoſition was well founded, but alſo that my experiments have been made with ſufficient preciſion to evince a mixture. Thus zinc alſo exactly follows the order of fuſibility, like the other metals and ſemi-metals, in the progreſs of heat, and does not make any exception to the rule. It cannot, therefore, in general be ſaid that the progreſs of heat in metals, ſemi-metals, and metallic minerals, is in the ſame ratio, or even nearly to that of their fuſibility.

III. The Vitreſcible and Vitreous Matters, which I tried, being ranged according to their denſity, are, pumice-ſtone, rock-chryſtal, and gres, for I muſt obſerve, that although chryſtal is not ſet down in the table of the weight of each matter but for ſix drachms 22 grains, it muſt be ſuppoſed one drachm heavier, becauſe it was inſenſibly too ſmall; and it was for this reaſon that I excluded it from the general table of relations; nevertheleſs as the general reſult agrees with the reſt, I can preſent the following as the order in which theſe different ſubſtances are cooled:

Pumice-ſtone, oker, porcelain, clay, glaſs, chryſtal, and gres, is according to that of their denſity, for the oker is here before the porcelain only becauſe, being a fuſible matter, it diminiſhed by the friction it underwent in the experiments, and, beſides, their denſity differs ſo little that they may be looked upon as equal.

Thus the law of the progreſs of heat in vitreſcible and vitreous matters is relative to the order of their denſity, and has little or no relation with their fuſibility but by the heat required to fuſe theſe ſubſtances being in an almoſt equal degree, and the particular degree of their different fuſibility being ſo near each other that a compound order of diſtinct terms cannot be made; thus their almoſt equal fuſibility making only one term, which is the extreme of this order, we muſt not be aſtoniſhed that the progreſs of heat here follows the order of denſity, and that theſe different ſubſtances, which are all equally difficult to fuſe, heat and cool more or leſs quick in proportion to the matter they contain.

It may be objected that glaſs fuſes more eaſily than clay, porcelain, oker, and pumice-ſtone, which, nevertheleſs, heat and cool in leſs time than glaſs; but the objection will fail when we reflect, that to fuſe glaſs it is requiſite to have a very fierce fire, the heat of which is ſo remote from the degrees which glaſs receives in our experiments on refrigeration, that it cannot have any influence on them. Beſides, by powdering clay, porcelain, and pumice-ſtone, and by giving them there analogous fuſers, as we give to ſand to convert it into glaſs, it is more than probable that we ſhould fuſe all the matters in the ſame degree of fire, and that, conſequently, we muſt look upon it as equal, or almoſt equal, with their reſiſtance to fuſion; and it is for this reaſon that the law of the progreſs of heat in theſe matters is found proportionable to the order of their denſity.

IV. Calcareous matters, ranged according to the order of their denſity, are, chalk, ſoft ſtone, hard ſtone, common marble, and white marble, which is the ſame as that of their denſity. The fuſibility does not enter therein as any thing, becauſe it immediately requires a very great degree of fire to calcine them; and although the calcination divides the parts, we muſt look upon the effect only as a firſt degree and not as a complete fuſion. The whole power of the beſt burning mirrors is ſcarcely ſufficient to perform it. I have found and reduced into a kind of glaſs ſome of theſe calcareous matters; and I am convinced that theſe matters may, like all the reſt, be reduced ulteriorly into glaſs, without employing thereto any fuſing matter, and only by the force of a fire ſuperior to that of our furnaces, conſequently the common term of their fuſibility is ſtill more remote, and more extreme, than that of vitreous matters, and it is for this reaſon that they alſo follow more exactly the order of denſity in the progreſs of heat.

White gypſum, improperly called alabaſter, is a matter which calcines like all other plaſters by a more moderate heat than that which is neceſſary for the calcination of calcareous matters, and it follows the order of denſity in the progreſs of heat which it receives or loſes, for although much more denſe than chalk, and a little ſo than white calcareous ſtone, it heats and cools more readily than either of thoſe matters. This demonſtrates that the more or leſs eaſy calcination and fuſion produces the ſame effects relatively to the progreſs of heat. Gypſous matters do not require ſo much fire to calcine as calcareous, and it is for this reaſon that, although more denſe, they heat and cool much quicker.

Thus it may be concluded, that, in general, the *progreſs of heat in all Mineral Subſtances is always nearly in a ratio of greater or leſs facility to calcine, or melt:* but when their calcination, or their fuſion, are *equally difficult*, and *that they require a degree of extreme heat*, then the *progreſs of extreme heat is made according to the order of their denſity.*

I have depoſited in the Royal Cabinet, the globes of gold, ſilver, and of all the other metallic and mineral ſubſtances which ſerved for the preceding experiments, that if the truth of their reſults, and the general conſequences which I have deduced, are doubted, there may be an opportunity of rendering them more authentic.

OBSERVATIONS ON THE NATURE OF PLATINA.

WE have already obſerved, that of all the Mineral Subſtances we ſubjected to trial, thoſe were not the moſt denſe which required the longeſt time to receive and loſe heat. Iron and emery, which are the moſt difficult matters to fuſe, are, at the ſame time, thoſe that heat and cool the ſloweſt. There is nothing except Platina that is acceſſible to heat, and which retains it longer than iron. This mineral, (which has not long been publicly mentioned) appears, however, to be more difficult to fuſe; the fire of the beſt furnaces is not fierce enough to produce that effect, nor even to agglutinate the ſmall grains, which are all angular, hard, and ſimilar in form to the thick ſcale of iron, but of a yellowiſh colour; and although we can fuſe them without any addition, and reduce them into a maſs by a mirror, platina ſeems to require more heat than the ore and ſcales of iron, which we eaſily fuſe in our forge furnaces. In other reſpects, the denſity of platina being much greater than that of iron, the two quantities of denſity and non-fuſibility unite here to render this matter the leaſt acceſſible to the progreſs of heat. I preſume, therefore, that platina would have been at the head of my table if I had put it to the experiment; but I was not able to procure a globe of it of an inch diameter, it being only found in grains; and that which is in the maſs is not pure, it being neceſſary, in order to fuſe it, to mix it with other matters, which alters its nature. The Comte de Billarderie d'Angivilliers, who often attended my experiments, led me to examine this rare metallic ſubſtance, not yet ſufficiently known. Chemiſts who have employed their time on platina, have looked upon it as a new, perfect, proper, and particular metal, different from all the reſt: they have aſſerted, that its ſpecific weight was nearly equal to that of gold; but that it eſſentially differed in other reſpects from gold, having neither ductility nor fuſibility. I own I am of a quite contrary opinion; becauſe a matter which has neither ductility nor fuſibility, cannot rank in the number of metals, whoſe eſſential and common properties are to be ductile and fuſible. Neither, after a very careful examination, did platina appear to me a new metal different from every other, but rather an alloy of iron and gold formed by Nature, in which the quantity of gold predominated over the iron, and I founded this opinion on the following facts:

Of 8 ounces 35 grains of platina, furniſhed me by Comte d'Angivilliers, which I preſented to a ſtrong loadſtone, there remained only 1 ounce, 1 dram, and 98 grains, all the reſt was taken away by the loadſtone; therefore, nearly ſix-ſevenths of the whole was attracted by the loadſtone, which is ſo conſiderable a quantity, that it is impoſſible to ſuppoſe that iron is not contained in the intimate ſubſtance of platina, but that it is even there in a very great quantity. I am convinced it contains much more, for if I had not been weary of theſe experiments, which took me up ſeveral days, I ſhould have attracted a great part of the remainder of the 8 ounces by my loadſtone, for to the laſt it continued to draw ſome grains one by one, and ſometimes two. There is, therefore, much iron in platina, and it is not ſimply mixed therewith as a foreign matter, but intimately united and making part of its ſubſtance;

or, if this is denied, it muſt be ſuppoſed, that there exiſts a ſecond matter in Nature which is attractable like iron by the loadſtone.

All the platina I have had an opportunity to examine, has appeared to be mixed with two different matters, the one black, and very attractable by the loadſtone; the other in larger grains, of a pale yellow, and much leſs magnetic than the firſt. Between theſe two matters, which are the two extremes, are found all the intermediate links, whether with reſpect to magnetiſm, colour, or ſize of the grains. The moſt magnetic, which are at the ſame time the blackeſt and ſmalleſt, reduce eaſily into powder by a very ſlight friction, and leave on white paper the ſame marks as lead. Seven leaves of paper which were ſucceſſively made uſe of to expoſe the platina to the action of the loadſtone, were blackened over the whole extent occupied by it; the laſt left leſs than the firſt, in proportion as the grains which remained were leſs black and magnetic; the largeſt grains, which are yellow, and leaſt magnetic, inſtead of crumbling into powder like the ſmall black grains, are very hard, and reſiſt all trituration; nevertheleſs, they are ſuſceptible of extenſion in an agate mortar, under the reiterated ſtrokes of a peſtle of the ſame matter,

ter, and I flattened and extended many grains to the double or treble extent of their ſurface: this part of platina has, therefore, a certain degree of malleability and ductility, whereas the black part appears to be neither malleable nor ductile. The intermediate grains participate of the qualities of the two extremes: they are brittle and hard, they break or extend under the ſtrokes of a peſtle, and afford a little powder not ſo black as the firſt.

Having collected this black powder and the moſt magnetic grains that the loadſtone had the firſt attracted, I diſcovered that the whole was iron, but in a different ſtate from common iron. The latter reduced into powder and filings contracts moiſture, and ruſts very readily; in proportion as the ruſt increaſes, it becomes leſs magnetic, and abſolutely loſes this magnetical quality when entirely and intimately ruſted; whereas this iron powder, or ferruginous ſand found in the platina, is inacceſſible to ruſt, how long ſoever it be expoſed to the air and humidity; it is alſo more infuſible and much leſs diſſoluble than common iron; but is, nevertheleſs, an iron which appears to differ only from common iron by a greater purity. This ſand is, in fact, iron diveſted of all the combuſtible matter and terrene parts found in common iron, and even in ſteel. It appears endowed and covered with a vitreous varniſh which defends it from all alteration. What is very remarkable, this pure iron ſand does not excluſively belong to the platina ore ; for I have found it, altho' always in ſmall quantities, in many parts where the iron ore has been dug which conſumed in my forges. As I ſubmitted to ſeveral trials all the ores I had, before I uſed them in my experiments, I was ſurpriſed to find in ſome of them, which were in grains, particles of iron, ſomewhat rounded and ſhining, like the filings of iron, and perfectly reſembling the ferruginous ſand of the platina ; they were all as magnetic, all as little fuſible, and all as difficult of ſolution. Such was the reſult of the compariſon I made on the ſand of platina, and of the ſand found in both my iron ores, at the depth of three feet, in earths where water eaſily penetrated. I was puzzled to conceive from whence theſe particles of iron could proceed, how they had been defended againſt ruſt for the ages they were expoſed to the humidity of the earth, and how this very magnetical iron might have been produced in veins of mines, which had not the ſmalleſt degree of that quality. I called experience to my aid to procure ſatisfaction on theſe points. I was well convinced that none of our iron ores in grain were tractable by the loadſtone, and well perſuaded that all iron ores, which are magnetical, have acquired that property only by the action of fire: that the mines of the north, which are ſo magnetical as to be ſought after by the compaſs, muſt owe their origin to fire, and are formed by the means, or the intermedium of water; from which I was induced to ſuppoſe that this ferruginous and magnetic ſand, that I found in a ſmall quantity in my iron mines, muſt owe its origin to fire, and having examined the place I was confirmed in this idea. This magnetical ſand is found in a wood, where, from time immemorial, they have made, and ſtill continue to make, coal furnaces. It is likewiſe more than probable that there were formerly conſiderable fires here. Coal and burnt wood produce iron droſs, which includes the moſt fixed parts of the iron that vegetables contain; it is this fixed iron which forms the ſand here ſpoken of, when the droſs is decompoſed by the action of the air, ſun, and rain, for then theſe pure iron particles, which are not ſubject to ruſt, nor to any other kind of alteration, ſuffer themſelves to be carried away by the water, and penetrate with it ſome feet deep into the earth. What I here advance may be verified by grinding the droſs well burnt, and there will be found a ſmall quantity of this pure iron, which, having reſiſted the action of the fire, equally reſiſts that of the ſolvents, and does not ruſt at all.

Being ſatisfied on this head, and having ſufficiently compared the ſand and droſs taken from the iron ores with that of the platina, not to doubt of their identity, it was not long before I was led to conclude, conſidering the ſpecific gravity of platina, that if this pure iron ſand, (proceeding from the decompoſition of droſs) inſtead of being in an iron mine, was found near to a gold one, it might, by uniting with that metal, form an alloy which would be abſolutely of the ſame nature as platina. Gold and iron have a great affinity; and it is well-known that moſt iron mines contain a ſmall quantity of gold; it is alſo known how to give to gold the tint, colour, and even the brittleneſs of iron, by fuſing them together. This iron-coloured gold is uſed on different golden jewels to vary the colours; and this gold mixed with iron is more or leſs grey, and more or leſs tempered, according to the quantity of iron which enters the mixture. I have ſeen it of a tint abſolutely like the colour of platina; and having enquired of a goldſmith the proportion of gold and iron therein, he informed me, that in a piece of 24 carats there were no more than 18 gold, conſequently a fourth part was iron, which is nearly the proportion found in the natural platina, if we judge of it by the ſpecific weight; and this gold made with iron is harder and ſpecifically leſs weighty than pure gold. All theſe agreements and common qualities with platina, have perſuaded me, that this pretended metal is, in fact, only an alloy of gold and iron, and not a particular ſubſtance, a new and perfect metal different from every other, as chemiſts have advanced.

It is well known that alloy makes all metals brittle, and that when there is a penetration, that is, an augmentation in the ſpecific gravity, the alloy is ſo much the more tempered as the penetration is the greater, and the mixture becomes the more intimate, as is perceived in the alloy called *bell-metal*, although it be compoſed of two very ductile metals. Now nothing is more tempered, nor heavier, than platina, which alone ought to make us conclude that it is only an alloy made by Nature, a mixture of iron and gold, owing in part its ſpecific gravity to this laſt, and, perhaps, alſo, in a great part, to the penetration of the two matters of which it is compoſed.

As this matter, heated alone and without any addition, is very difficult to reduce into a maſs, as by the fire of a burning mirror we can obtain only very ſmall maſſes, and as the hydroſtatical experiments made on ſmall volumes are ſo defective, that we cannot conclude any thing therefrom, it appears to me that the chemiſts have been deceived in their eſtimation of the ſpecific gravity of this mineral. I put ſome powder of gold in a little quill, which I weighed very exactly: I put in the ſame quill an equal volume of platina, and it weighed nearly a tenth leſs; but this gold powder was much too fine in compariſon of the platina. M. Tillet, who, beſides a profound knowledge of metals, poſſeſſed the talent of making experiments with the greateſt preciſion, repeated, at my requeſt, this upon the ſpecific weight of platina, compared to pure gold; for this purpoſe, he, like me, made uſe of a quill, and cut gold of 24 carats, reduced as much as poſſible to the ſize of the grains of platina, and he found, by eight experiments, that the weight of platina differed from that of pure gold very near a fifteenth; but we both obſerved that the grains of gold had much ſharper angles than the platina: all the angles of the latter were blunt, and even ſoft, whereas the grains of this gold had ſharp and cutting angles, ſo that they could not adjuſt themſelves, nor heap one on the other as eaſily as thoſe of platina. The gold powder I had before made uſe of was ſuch as is found in river ſand, whoſe grains adjuſt themſelves much better one againſt the other, and I found about a tenth difference between the ſpecific weight of thoſe and platina; nevertheleſs, thoſe are not pure gold, more than two or three carats being often wanting, which muſt diminiſh the ſpecific weight in the ſame relation. Thus we have thought we might maintain, from the reſult of my experiments, that platina in grains, and ſuch as Nature produces it, is, at leaſt, an eleventh, or twelfth, lighter than gold. There is every appearance that the error, on the denſity of platina, proceeded from its not having been weighed in its natural ſtate, but only after it had been reduced into a maſs; and as this fuſion cannot be made but by the addition of other matters, and a very fierce fire, it is no longer pure platina, but a compoſition in which fuſing matters are entered, and from which fire has taken the lighteſt parts.

Platina, therefore, inſtead of being of an almoſt equal denſity to that of pure gold, as has been aſſerted, is only a denſity between that of gold and iron, and only nearer this firſt metal than the laſt. For ſuppoſing that the cube foot of gold weighed 1326lb. and that of iron 280, that of platina in grains will be found to weigh about 1194lb. which ſuppoſes more than $\frac{3}{4}$ of gold to $\frac{1}{4}$ of iron in this alloy, if there is no penetration ; but as we extract $\frac{6}{7}$ by the loadſtone, it might be thought, that there is more than $\frac{1}{4}$ iron therein ; eſpecially as by continuing this experiment, I am perſuaded, we ſhould be able, with a ſtrong loadſtone to bring away all the platina even to the laſt grain. Neverthelеſs, we muſt not conclude that iron is contained therein in ſo great a quantity ; for when it is mixed by the fuſion with gold, the maſs which reſults from this alloy is attractable by the loadſtone, although the iron is in no great quantity therein. M. Baume had a piece of this alloy weighing 66 grains, in which was only entered 6 grains, that is, $\frac{1}{11}$ of iron, and this button was eaſily taken up by the loadſtone. Hence the platina might poſſibly contain only $\frac{1}{11}$ iron, or $\frac{16}{11}$ gold, and yet be attracted entirely by the loadſtone ; and this perfectly agrees with the ſpecific weight which is $\frac{1}{12}$ leſs than gold.

But what makes me preſume, that platina contains more than $\frac{1}{11}$ of iron, or $\frac{16}{11}$ of gold, is, that the alloy from this proportion is ſtill of the gold colour, and much yellower than the higheſt coloured platina, and that $\frac{1}{4}$ iron, or $\frac{3}{4}$ gold is requiſite for the alloy to be preciſely of the natural colour of platina. I am, therefore, greatly inclined to think that there might poſſibly be this quantity of $\frac{1}{4}$ iron in platina. We were aſſured by many experiments, that the ſand of this pure iron which contained platina, is heavier than the filings of common iron. Thus, this cauſe, added to the effect of penetration, is ſufficient for the reaſon of this great quantity of iron contained under the ſmall volume indicated by the ſpecific weight of platina.

On the whole, it is very poſſible that I am deceived in ſome of the conſequences which I have drawn from my obſervations on this metallic ſubſtance; I have not been able to make ſo profound an examination as I could wiſh; what I ſay is only what I have obſerved, and may perhaps ſerve for better inſpections.

Chance led me to tell my ideas to Comte de Milly, who declared himſelf nearly of my opinion. I gave him the preceding remarks to inſpect, and two days after he favoured me with the following obſervations, and which he has permitted me to publiſh.

"I weighed exactly thirty-ſix grains of platina; I laid them on a ſheet of white paper that I might obſerve them the better with a loup; I perceived three different ſubſtances; the firſt had the metallic luſtre, and was the moſt abundant; the ſecond, drawing a little on the black, pretty well reſembled a ferruginous metallic matter, which could undergo a conſiderable degree of fire, ſuch as the ſcoria of iron, vulgarly called *machefer:* the third leſs abundant than the two firſt, i. e. ſand, where the yellow, or topaz colour, is the moſt predominant. Each grain of ſand, conſidered ſeparate, offered to the ſight regular chryſtals of different colours. I remarked ſome in an hexagon form, terminating in pyramids like rock chryſtal; and this ſand ſeems to be no other than a *detritus* of chryſtal, or quartz of different colours.

"I reſolved on ſeparating, as exactly as poſſible, theſe different ſubſtances by means of the loadſtone, and to put aſide the parts moſt attractable by the loadſtone, from theſe which were leſs, and both from thoſe which were not ſo at all; then to examine each ſubſtance particularly, and to ſubmit them to different chemical and mechanical heats.

" I ſeparated theſe parts of the platina which were briſkly attracted at the diſtance of two or three lines; that is to ſay, without the contact of the loadſtone; and for this experiment I made uſe of a good factitious magnet; I afterwards touched the metal with this magnet, and carried off all that would yield to the magnetical force. Being ſcarcely any longer attractable, I weighed what remained, and which I ſhall call No. 4, weighed twenty-four grains; No. 1, which was the moſt ſenſible to the magnet, weighed four grains; No. 2 weighed the ſame; and No. 3 five grains.

" No. 1. examined by the loup, preſented only a mixture of metallic parts, a white ſand bordering on the greyiſh, flat and round, or black vitriform ſand, reſembling pounded ſcoria, in which very ruſty parts are perceptible: in ſhort, ſuch as the ſcoria of iron preſents after having been expoſed to moiſture.

" No. 2 preſented nearly the ſame, excepting that the metallic parts predominated, and that there were very few ruſty particles.

" No. 3 was the ſame, but the metallic parts were more voluminous; they reſembled melted metal which had been thrown into water to be granulated; they were flat, and of all ſorts of figures, rounded on the corners.

"No. 4, which had not been carried off by the magnet (but ſome parts of which ſtill afforded marks of ſenſibility to magnetiſm, when the magnet was moved under the paper where they were in), was a mixture of ſand, metallic parts, and real ſcoria, friable between the fingers, and which blackened in the ſame manner as common ſcoria. The ſand ſeemed to be compoſed of ſmall rock, topaz, and cornelian chryſtals. I broke ſome on a ſteel, and the powder was like varniſh reduced into powder; I did the ſame to the ſcoria; it broke with the greateſt facility, and preſented a black powder which blackened the paper like the common.

"The metallic parts of this laſt (No. 4) appeared more ductile under the hammer than thoſe of No. 1, which made me imagine they contained leſs iron than the firſt: from whence it follows, that platina may poſſibly be no more than a mixture of iron and gold made by Nature, or perhaps by the hands of men.

"I endeavoured to examine, by every poſſible means, the nature of platina: to aſſure myſelf of the preſence of iron of platina by chemical means, I took No. 1, which was very attractable by the magnet, and No. 4, which was not; I ſprinkled them with fuming ſpirit of nitre; I immediately obſerved it with the microſcope, but perceived no effervеſcence: I added diſtilled water thereon, and it ſtill made no motion, but the metallic parts acquired new brilliancy, like ſilver: I let this mixture reſt for five or ſix minutes, and having ſtill added water, I threw ſome drops of alkaline liquor ſaturated with the colouring matter of Pruſſian blue, and a very fine Pruſſian blue was afforded me on the firſt.

"No. 4, treated in the ſame manner, gave the ſame reſult. There are two things very ſingular to remark in theſe experiments; firſt, That it paſſes current among chemiſts who have treated on the platina, that aquafortis, or ſpirit of nitre, has no action on it. Yet, as I have juſt obſerved, it diſſolves it ſufficiently, though without effervеſcence, to afford Pruſſian blue, when we add the alkaline liquor phlogiſticated and ſaturated with the colouring matter, which, as is known, precipitates iron into Pruſſian blue.

"Platina, which is not ſenſible to the magnet, does not contain leſs iron, ſince ſpirits of nitre diſſolves it enough and without effervеſcence to make Pruſſian blue. From whence it follows, that this ſubſtance which the modern chemiſts, perhaps too greedy of the marvellous, and willing to give ſomething novel, have conſidered as a ninth metal, may poſſibly be only a mixture of gold and iron.

"Without doubt there ſtill requires many experiments to determine how this mixture has taken place, if it is the work of Nature or the effects of ſome volcano, or ſimply the produce of the Spaniards labours in the New World to acquire gold in the mines of Peru.

"If we rub platina on white linen it blackens it like common ſcoria, which made me ſuſpect that it is the parts of iron reduced into ſcoria found in this platina which gives it this colour, and which ſeem, in this ſtate, only to have tried the action of a violent fire. Beſides, having a ſecond time examined platina with my loup, I perceived therein different globules of running mercury, which made me ſuppoſe that platina might be the produce of the hands of man, in the following manner:—Platina, as I have been told, is taken out of the oldeſt mines in Peru, which the Spaniards explored after the conqueſt of the New World. In thoſe dark times only two methods were known of extracting gold from the ſands which contained it; firſt, by an amelgama with mercury; ſecondly, by drying it. The golden ſand was rubbed with quickſilver, and when that was judged to be loaded with the greateſt part of the gold, the ſand was thrown away, which was named *craſſe*, as uſeleſs and of no value.

" This method was made with very little judgment; to extract it they began by exciting auriferous metals by means of ſulphur, which has no action on gold, the ſpecific weight being greater than that of other metals; but to facilitate its precipitation iron was added, which loaded itſelf with the ſuperabundant ſulphur, and this method is ſtill followed. The force of fire vitrifies one part of the iron, the other combines itſelf with a ſmall portion of the gold, or even ſilver, which mixes with the ſcoria, from whence it cannot be drawn but by ſtrong fuſions, and being well inſtructed in the ſuitable intermediums which are made uſe of. Chemiſtry, which is now arrived to great perfection, affords, in fact, means to extract the greateſt part of this gold and ſilver: but at the time when the Spaniards explored the mines of Peru, they were, doubtleſs, ignorant of the art of mining with the greateſt profit; beſides, they had ſuch great riches at their diſpoſal that they, probably, neglected the means which would have coſt them trouble, care, and time; therefore there is much reaſon to conclude that they contented themſelves with a firſt fuſion, and threw away the ſcoria as uſeleſs, as well as the ſand which had eſcaped the quickſilver, and perhaps they made a mere heap of theſe two mixtures, which they regarded as of no value.

“ Their ſcoria contained gold and much iron under different ſtates, and that in different proportions unknown to us, but which, perhaps, are thoſe that gave origin to the platina. The globules of quickſilver, which I have obſerved, and thoſe of gold, which I have diſtinctly ſeen, with the aſſiſtance of a good loup, in the platina I had in my hands, have given birth to the ideas which I have written on the origin of this mineral; but I only give them as hazardous conjectures. To acquire ſome certainty we muſt be preciſely where the platina mines are ſituated, and examine if they have been anciently explored, whether it is extracted from a new ſoil, or if the mines are only rubbiſh, and to what depth they are found; and, laſtly, if they have any appearance of being placed by the hands of man there or not, which alone can verify or deſtroy the conjectures I have advanced.”

Theſe obſervations of Comte de Milly confirm mine in almoſt every point. Nature is the ſame, and preſents herſelf always the ſame to thoſe who know how to obſerve her: thus we muſt not be ſurprized that, without any communication, we obſerved the ſame things, and deduced the ſame conſequence therefrom ; that platina is not a new metal, different from every other, but a mixture of iron and gold. To reconcile his obſervations ſtill more with mine, and to enlighten, at the ſame time, the doubts which remain on the origin and formation of platina, I have thought it neceſſary to add the following remarks :

1. The Comte de Milly diſtinguiſhes three kinds of matters in platina, namely, two metallic, and the third non-metallic, of a chryſtalline form and ſubſtance. He obſerved, as well as me, that one of the metallic matters is very attractable by the magnet, and the other but little, or not at all. I mentioned theſe two matters as well as him, but I did not ſpeak of the third, which is not metallic, becauſe there was none, or very little, in the platina on which I have made my obſervations. There is an appearance that the platina which the Comte made uſe of was not ſo pure as mine, which I obſerved with the greateſt care, and in which I ſaw only ſome ſmall tranſparent globules, like white melted glaſs, which were united to the particles of platina, or ferruginous ſand, and which were carried any where by the magnet.

Theſe tranſparent globules were very few, and in eight ounces of platina, which we narrowly inſpected with a very ſtrong loup, we never perceived regular chryſtals. It rather appeared to me that all the tranſparent particles were globulous, like melted glaſs, and all attached to metallic parts; nevertheleſs, as I did not in the leaſt doubt of the veracity of Comte de Milly's obſervation, who obſerved chryſtalline particles of a regular form, and in a great number, in his platina, I thought I ought not to confine myſelf ſolely to the examination of that platina of which I have ſpoken; and finding ſome in the king's cabinet, M. Daubenton and I examined it together: this appeared to be much leſs pure than that we had before made our experiments on; and in it we remarked a great number of ſmall priſmatic and tranſparent chryſtals, ſome of a ruby colour, others of a topaz, and others perfectly white, which convinced us of the correctneſs of the Comte de Milly in his obſervations; but this only proves that there are ſome mines of platina much more pure than others, and that in thoſe which are the moſt ſo none of theſe foreign bodies are found. M. Daubenton alſo remarked ſome grains flat at bottom and rough at top, like melted metal cooled on a plain, and I very diſtinctly ſaw one of theſe hemiſpherical grains, which might indicate that platina is a matter that has been melted by the fire; but it is very ſingular, that in this matter, if melted by fire, ſmall chryſtals, topaz, and rubies, are found; and I do not know whether we ought not to ſuſpect fraud in thoſe who ſupplied this platina, who, to increaſe the quantity, mixed it with theſe chryſtalline ſands, for I never met with theſe chryſtals but in one half pound of platina, given me by the Comte de Angivilliers.

2. I, as well as Comte de Milly, found gold ſand in platina; it is readily diſcovered by its colour, and becauſe it is not magnetical; but I own that I never perceived the globules of mercury which he ſtates to have done; but I do not mean from thence to deny their exiſtence, only that it appears to me that the ſand of gold meeting with the globules of mercury, in the ſame matter, they might be ſoon amalgamated, and not retain the colour of gold, which I have remarked in all the gold ſand that I could find in half a pound of platina; beſides, the tranſparent globules, which I have juſt ſpoken of, reſemble greatly the globules of live and ſhining mercury, inſomuch that at the firſt glance it is eaſy to be deceived therein.

3. There were by no means ſo many tarniſhed and ruſty parts in my firſt platina as in that of Comte de Milly's, nor was it properly a ruſt which covered the ſurface of thoſe ferruginous particles, but a black ſubſtance produced by fire, and perfectly ſimilar to that which covers the ſurface of burnt iron. But my ſecond platina, that which I had from the royal cabinet, had a mixture of ſome ferruginous parts, which under the hammer were reduced into a yellow powder, and had all the characters of ruſt. Therefore this platina of the royal cabinet, and that of Comte de Milly, reſembling in every reſpect, it is probable that they proceeded from the ſame part, and by the ſame road. I even ſuſpect that both had been ſophiſticated and mixed above half with foreign chryſtalline and ferruginous ruſty matters, which are not met with in the natural platina.

4. The production of Pruſſian blue by platina, appears evidently to prove the preſence of iron in thoſe parts of this mineral, which are the leaſt attractable by the magnet, and at the ſame time confirms what I have advanced on the intimate mixture of iron in its ſubſtance. The flowing of platina by ſpirits of nitre, alſo proves that, although it has no ſenſible efferveſcence, this acid attracts the platina in an evident

manner; and the authors, who have aſſerted the contrary, have followed their common track, which conſiſts on looking on all actions as null which do not produce an effervefcence. Theſe ſecond experiments of the Comte de Milly, would appear very important, if they ſucceeded always alike.

5. We muſt however admit that, in fact, many eſſential matters are wanting to pronounce affirmatively on the origin of platina. We know nothing of the natural hiſtory of this mineral, and we cannot too greatly exhort thoſe who are inclined to examine it on the ſpot, to make known their obſervations; and until that is done we muſt confine ourſelves to conjectures, ſome of which appear only more probable than others. For example, I do not imagine platina to be the work of man. The Mexicans and Peruvians knew how to force and work gold before the arrival of the Spaniards, and they were not acquainted with iron, which nevertheleſs they muſt have employed in a great quantity. The Spaniards themſelves did not eſtabliſh furnaces to fuſe iron in this country, when they firſt inhabited it. There is, therefore, every reaſon to conclude, that they did not make uſe of the filings of iron for the ſeparation of gold, at leaſt in the be-

ginning of their labours, which does not go above two centuries and a half back; a time much too ſhort for ſo plentiful a production as platina, which is found in large quantities in many places.

Beſides, when gold is mixed with iron, by fuſing them together, we may always, by chemiſtry, ſeparate them, and extract the gold: whereas, hitherto chemiſts have not been able to make this ſeparation in platina, nor determine the quantity of gold contained in this mineral. This ſeems to prove, that gold is united therewith in a more intimate manner than the common alloy, and that iron is alſo therein, in different ſtate from that of common iron. Platina, therefore, appears to me to be the production of nature, and, I am greatly inclined to think, that it owes its firſt origin to the fire of Volcanos. Burnt iron, intimately united with gold by ſublimation, or fuſion, may have produced this mineral, which having been at firſt formed by the action of the fierceſt fire, will afterwards have felt the impreſſions of water, and the reiterated frictions, which have given it the form of blunt angles. But water alone might have produced the platina; for ſuppoſing gold and iron divided as much as poſſible by the humid mode, their molecules, by uniting, will have formed the grains which compoſe it, and which from the heavieſt to the lighteſt contain gold and iron ; the propoſition of the chemiſt who offers to render *nearly* as much gold as they ſhall furniſh him with platina, ſeems to indicate, that there, in fact, is only $\frac{1}{11}$ of iron to $\frac{1}{10}$ of gold in this mineral, or poſſibly leſs. But the *nearly* of this chemiſt is probably a fifth, or a fourth, and, indeed, if he could realize his promiſe to a fourth, it would be doing a great deal, and no vain boaſt.

Being at Dijon the ſummer of 1773, the Academy of Sciences and Belles Lettres expreſſed a deſire of hearing my obſervations on platina ; and having complied, M. de Morteau took the reſolution of making ſome experiments on this Mineral ; for which purpoſe I gave him a portion of that I had attracted by the loadſtone, and alſo ſome which I had found inſenſible to magnetiſm, requeſting him to expoſe it to the ſtrongeſt fire he could poſſibly make. Some time after, he ſent me the following experiments which he was pleaſed to ſubjoin to mine.

"Monſieur the Comte de Buffon, in a journey to Dijon, the ſummer of 1773, having cauſed me to remark in half a dram of platina, which M. de Baume had ſent him in 1768, grains in form of buttons, others flatter, and ſome black and ſcaly ; and having ſeparated by the loadſtone thoſe which were attractable from thoſe which appeared not ſo, I tried to form Pruſſian blue with both. I ſprinkled the fuming nitrous acid on the non-attractable parts, which weighed $2\frac{1}{2}$ grains. Six hours after I put diſtilled water on the acid, and ſprinkled alkaline liquor, ſaturated with a colouring matter ; however there was not a ſingle atom of blue, the platina had only a little more brightneſs. I alike ſprinkled the fuming acid on the remaining platina, part of which was attractable, the ſame Pruſſian alkali precipitated a blue feculency, which covered the bottom of a pretty large baſon. The platina, after this operation, ſhewed like the firſt. I waſhed and dried it, and found it had not loſt $\frac{1}{4}$ of a grain, or $\frac{1}{138}$ part ; having examined it in this ſtate I perceived a grain of beautiful yellow, which was pure gold.

" M. de Fourcy had newly publiſhed, that the diſſolution of gold was thrown down in a blue precipitate by the Pruſſian alkali, and had placed this circumſtance in a table of affinity ; I was tempted to repeat this experiment, and ſprinkled, in conſequence thereof, the phlogiſticated alkaline liquor in the diſſolution of gold, but the colour of this diſſolution did not change; which made me ſuſpect that the diſſolution of gold, made uſe of by M. de Fourcy, might poſſibly have not been ſo pure.

"At the ſame time the Comte de Buffon having given me a ſufficient quantity of platina to make further aſſays, I undertook to ſeparate it from all foreign bodies by a good font; and I have here ſubjoined the proceſſes and reſults which I met with.

EXPERIMENTS.

"I. Having put a drachm of platina, in a cupel, into a furnace, I kept up the fire two hours, when the covers ſunk down, the ſupporters having run, nevertheleſs the platina was only agglutinated; it ſtuck to the cupel, and had left ſpots of a ruſty colour. The platina was then tarniſhed even a little black, and had only augmented a grain of weight; a quantity very weak in compariſon with that which other chemiſts have obſerved. What ſurpriſed me ſtill more was, that this drachm of platina, as well as all that I uſed for other experiments, had been ſucceſſively carried away by the loadſtone,

ſtone, and made a portion of $\frac{6}{7}$ of eight ounces, of which the Comte de Buffon has before ſpoken.

" II. Half a drachm of the ſame platina, expoſed to the ſame fire in a cupel, was alſo agglutinated; it adhered to the cupel, on which it had left ſpots of a ruſty colour; the augmentation of weight was found to be nearly in the ſame proportion, and the ſurface as black.

" III. I put this half drachm into a new cupel, but inſtead of the cover I placed over it a leaden crucible. This I kept in the moſt extreme heat for four hours; when it was cooled I found the crucible ſoldered to the ſupport, and having broken it I perceived that nothing had penetrated into the internal part of the crucible, which appeared to be only more gloſſy than before. The cupel had preſerved its form and poſition, it was a little cracked, but not enough to admit of any penetration; the platina was alſo not adherent to it, though agglutinated, but in a much more intimate manner than in the firſt experiments; the grains were leſs angular, the colour more clear, and the brilliancy more metallic. But what was moſt remarkable during the operation, there iſſued from its ſurface, probably in the firſt moments of its refrigeration, three drops of water, one of which, that aroſe perfectly ſpherical, was carried up on a ſmall pedicle of the vitreous and tranſparent matter. It was of an uniform colour, with a ſlight tint of red, which did not deprive it of any tranſparency; the ſmalleſt of the other two drops had likewiſe a pedicle, and the other none, but was only attached to the platina by its external ſurface."

"IV. I endeavoured to aſſay the platina, and for that intent put a drachm of the grains taken up by the loadſtone into a cupel, with two drachms of lead. After having kept up a very ſtrong fire for two hours I found an adherent button, covered with a yellowiſh and ſpungeous cruſt of two drachms twelve grains weight, which announces that the platina had retained one drachm twelve grains of lead. I put this button into another cupel in the ſame furnace, obſerving to turn it, by which it only loſt twelve grains in two hours; its colour and form were very little changed. The ſame piece of platina was put into Macquer's furnace, and a fire kept up for three hours, when I was obliged to take it out, becauſe the bricks began to run. The platina was become more metallic, but it, neverthelеſs, adhered to the cupel, and this time it loſt 34 grains. I threw it into the fuming nitrous acid to aſſay it, and there ariſing a little effervefcence, I added diſtilled water thereon. The platina loſt two grains, and I remarked ſome ſmall holes, like thoſe which its flying off might occaſion.

"There then remained only 22 grains of lead in the platina. I began to form a hope of vitrifying this remaining portion of lead, for which purpoſe I put the ſame piece of platina into a new cupel, and by the care I took for the admiſſion of air, and other precautions, the activity of the fire was ſo greatly augmented that it required a ſupply every eleven minutes; to this degree of heat we kept it for four hours, and then permitted it to cool.

"I perceived the next morning that the leaden crucible had reſiſted, and that the ſupporters were only glazed by the cinders. I found a piece in the cupel, no way adherent, of an uniform colour, approaching more the colour of tin than any other metal, but only a little ragged. It weighed exactly one drachm. All, therefore, announced that this platina had endured a perfect fuſion, and that it was perfectly pure, for if we ſuppoſe it ſtill contained lead, we muſt then admit that it had loſt exactly as much of its own ſubſtance as it had gained of foreign matter; and ſuch a preciſion cannot be the effect of pure chance.

" I paſſed ſeveral days with M. Buffon, whoſe company has the ſame charms as his ſtyle, and whoſe converſation is as complete as his books: I took a pleaſure in preſenting him with the production of my aſſays; we examined them together, and obſerved, Firſt, that the drachm of platina, agglutinated by theſe experiments, was not attractable by the loadſtone; that, nevertheleſs, the magnetical bar had an action on the grains that were looſened from it.

" 2. The half drachm of the third experiment was not only attractable in the maſs, but the grains of gold ſeparated therefrom, did not themſelves give any ſign of magnetiſm.

" 3. The platina of the fourth experiment was abſolutely inſenſible to the loadſtone.

" 4. The ſpecific weight of this piece was determined by a good hydroſtatical balance, and for the greater certainty, compared to coined, and to other very pure gold, uſed by M. Buffon in his experiments, their denſity was found, with water, in which they were plunged,

Pure gold	-	$19 \frac{8}{1}^{4}$
Coin gold	-	$17 \frac{1}{2}$
Platina	-	$14 \frac{2}{5}$

" 5. This piece of platina was put upon ſteel to try its ductibility; it ſupported the hammer very well for a few ſtrokes; its ſurface became flat and even, a little ſmooth in the parts which were ſtruck, but it ſplit ſoon after, and nearly a ſixth part ſeparated. The fracture preſented many cavities, ſome of which had the whiteneſs and brilliancy of ſilver, and in others we remarked ſeveral points like chryſtalization; the tops of theſe points examined with the loup, was a globule abſolutely ſimilar to that of the third experiment. All the other parts of this piece of platina were compact, the grain finer and cloſer than the beſt braſs, which it reſembled in colour. We offered ſeveral of theſe pieces to the loadſtone, but not one was attracted thereby. We powdered them again in an agate mortar, and then remarked that the magnetical bar raiſed up ſome of the ſmalleſt every time they were placed under it.

"This new appearance of magnetiſm was ſo much the more ſurpriſing, as the grains were detached from the agglutinated maſs of the ſecond experiment, which ſeemed to have loſt all ſenſibility at the approach and contact of the loadſtone. In conſequence we again took ſome of theſe grains, which were alike powdered, and ſoon perceived the ſmalleſt parts ſenſibly attach themſelves to the magnetic bar. It is impoſſible to attribute this effect to the ſmoothneſs of the bar, or to any other cauſe foreign to magnetiſm. A piece of ſmooth iron, applied in the ſame manner on the parts of this platina, did not raiſe up a ſingle grain.

"By theſe experiments, and the obſervations which have ariſen therefrom, we may judge of the difficulty of determining the nature of platina. It is very certain that it contains ſome parts which are vitrifiable even without the addition of a fierce fire; it is alſo certain that all platina contains iron and attractable parts; but if the Pruſſian alkali never affords blue but with the grains which the loadſtone attracts, we ſhould conclude, that thoſe which reſiſt it are pure platina, which of itſelf has no magnetical virtue, and of which iron does not make an eſſential part. We muſt ſuppoſe that a ſufficient fuſion, or perfect cupellation might decide this queſtion; at leaſt, theſe operations appear to have, in fact, deprived it of every magnetic virtue, by ſeparating it from all foreign bodies; but the laſt obſervation proves, in an incontrovertible manner, that this magnetic property was, in reality, only weakened, and perhaps maſked or buried, ſince it re-appeared when it was ground."

From theſe experiments of M. de Morteau there reſults, 1. That we may expect platina to be melted without addition, by applying the fire to it ſeveral times ſucceſſively, becauſe the beſt crucibles might not reſiſt the action of ſo fierce a fire during the whole time as the complete operation would require.

2. That by melting it with lead, and aſſaying them ſeveral times, we ſhould in the end vitrify all the lead and the platina; and that this experiment would be able to purge it from a part of the foreign matters it contains.

3. That by melting it without any addition, it ſeems to purge itſelf partly into the vitreſcible matters it includes, ſince it emits to its ſurface ſmall drops of glaſs which form pretty conſiderable maſſes, and that we can eaſily ſeparate them after refrigeration.

4. That by making experiments on Pruſſian blue with the grains of platina, which appeared to be moſt inſenſible to the loadſtone, we were not always certain of obtaining it, a circumſtance which never fails with grains that have more or leſs ſenſibility to magnetiſm.

5. It appears that neither fuſion nor cupellation can deſtroy all the iron with which platina is intimately penetrated; the pieces melted or aſſayed, appeared, in reality, equally as ſenſible to the action of the loadſtone; but, having pounded them in a mortar, we found magnetical

parts; ſo much the more abundant as the platina was reduced into a finer powder. The firſt piece, whoſe grains were only agglutinated, being ground, rendered many more magnetical parts than the ſecond and third, the grains of which had undergone a ſtronger fuſion; but, nevertheleſs, being both ground, they furniſhed magnetical parts; inſomuch that it cannot be doubted that there is iron in platina, after it has undergone the fierceſt efforts of fire, and the devouring actions of the heat in the cupel. This demonſtrates, that this mineral is really an intimate mixture of gold and iron, which hitherto art has not been able to ſeparate.

6. We made another obſervation with M. Morteau on melted, and afterwards on ground platina; namely, that it takes in grinding preciſely the ſame form as it had before it had been melted; all the grains of this melted and ground platina are ſimilar to thoſe of the natural, as well in form, as variety of ſize; and they appear to differ only becauſe the ſmalleſt alone ſuffer themſelves to be raiſed by the loadſtone, and in ſo much the leſs quantity as the platina has endured the fire. This ſeems alſo to prove, that, although the fire has been ſtrong enough not only to burn and vitrify, but even to drive off a part of the iron with other vitreſcible

matter which it contains; the fuſion, nevertheleſs, is not ſo complete as that of other perfect metals, ſince, in grinding, it retakes the ſame figure as it had before fuſion.

EXPERIMENTS ON LIGHT, AND ON THE HEAT IT MAY PRODUCE.

INVENTION OF MIRRORS TO BURN AT GREAT DISTANCES.

THE ſtory of the burning glaſſes of Archimedes is famous; he is ſaid to have invented them for the defence of his country; and according to the ancients, he reflected the fire of the ſun with ſuch force on the enemy's fleet, as to reduce them into aſhes on their approaching the ramparts of Syracuſe. But this ſtory, of which no doubt was made for fifteen or ſixteen centuries, has been contradicted and treated as fabulous in theſe latter ages. Deſcartes, in a maſterly manner, has attacked this talent attributed to Archimedes; he has denied the poſſibility of the invention, and his opinion has prevailed over the teſtimonies and credit of the ancients. Modern phyſicians; either thro' a reſpect for their philoſopher, or thro' complaiſance for their cotemporaries, have given in to the ſame opinion. Nothing is allowed to the ancients but what cannot be avoided. Determined, perhaps, by theſe motives, of which ſelf-love too often is the abettor, have we not naturally too much inclination to refuſe what is due to our predeceſſors? and if, in our time, more is refuſed than was in any other, is it not that by being more enlightened, we think we have more right to fame, and more pretenſions to ſuperiority?

Be that as it may, this invention was the cauſe of many other diſcoveries of antiquity at preſent vaniſhed, becauſe the facility of denying them has been preferred to the trouble of finding them out; and the burning-glaſſes of Archimedes have been ſo decried, that it does not appear poſſible to re-eſtabliſh the reputation; for, to call the judgment of Deſcartes in queſtion, ſomething more is required than aſſertions, and there only remained one ſure deciſive mode, but at the ſame time, difficult and bold, which was to undertake to diſcover glaſſes that might produce the like effects.

Though I had conceived the idea, I was for a long time deterred from making the experiment by the dread of the difficulty which might attend it; at length, however, I determined to ſearch after the mode of making mirrors to burn at a great diſtance, as from 100 to 300 feet. I knew, in general, that the power of reflecting mirrors, never extended farther than 15 or 20 feet, and with refringent, the diſtance was ſtill ſhorter; and I perceived it was impoſſible by practice to form a metal, or glaſs mirror with ſuch exactneſs as to burn at theſe great diſtances. To have ſufficient power for that, the ſphere, for example, muſt be 800 feet diameter; therefore, we could hope for nothing of that kind in the common mode of working glaſſes; and I ſoon perceived that if we could find a new method to give to large pieces of glaſs, or metal, a curve ſufficiently ſlight, there would ſtill reſult but a very inconſiderable advantage.

But to proceed regularly, it was neceſſary firſt to ſee how much light the ſun loſes by reflection at different diſtances, and what are the matters which reflect it the ſtrongeſt; I firſt found, that glaſſes when they are poliſhed with care, reflect the light more powerfully than the beſt poliſhed metals, and even better than the compounded metal with which teleſcope mirrors are made; and that although there are two reflections in the glaſſes, they yet give a brighter and more clear light than metal. Secondly, by receiving the light of the ſun in a dark place, and by comparing it with this light of the ſun reflected by a glaſs, I found, that at ſmall diſtances, as four or five feet, it only loſt about half by reflection, which I judged by letting a ſecond reflected light fall on the firſt; for the briſkneſs of theſe two reflected lights appeared to be equal to that of direct light. Thirdly, having received at the diſtances of 100, 200, and 300 feet, this light reflected by great glaſſes, I perceived that it did not loſe any of its ſtrength by the thickneſs of the air it had to paſs through.

I afterwards tried the ſame experiments on the light of candles, and to aſſure myſelf more exactly of the quantity of weakneſs that reflection cauſes to this light, I made the following experiments:

I ſeated myſelf oppoſite a glaſs mirror with a book in my hand, in a room where the darkneſs of the night would not permit me to diſtinguiſh a ſingle object. In an adjoining room I had a lighted candle placed at about 40 feet diſtance; this I approached nearer and nearer, till I could read the book, when the diſtance was about 24 feet. Afterwards turning the book, I endeavoured to read by the reflected light, having by a parchment intercepted the part of the light which did not fall on the mirror, in order to have only the reflected light on my book. To do ſo I was obliged to approach the candle nearer, which I did by degrees, till I could read the ſame characters clearly by the ſame light, and then the diſtance from the candle, comprehending that of the book to the mirror, which was only half a foot, I found to be in all 15 feet. I repeated this ſeveral times, and had always nearly the ſame reſults; from whence I concluded, that the ſtrength, or quantity, of direct light is to that of reflected light, as 576 to 225; therefore, the light of five candles reflected by a flat glaſs, is nearly equal to that of the direct light of two.

The light of a candle, therefore, loſes more by reflection than the light of the ſun; and this difference proceeds from the rays of the former falling more obliquely on the mirror than the rays of the ſun, which come almoſt parallel. The experiment confirms what I had at firſt found, and I hold it certain, that the light of the ſun loſes only half by its reflection on a glaſs mirror.

This firſt information, of which I had need, being acquired, I afterwards ſought what became of the images of the ſun when received at great diſtances. To be perfectly underſtood we muſt not, as is generally done, conſider the rays of the ſun as parallel; and it muſt alſo be remembered, that the body of the ſun occupies an extent of about 32 minutes; that the rays, which iſſue from the upper edge of the diſk, falling on a point of a reflecting ſurface, the rays, which iſſue from the lower edge, falling alſo on the ſame point of this ſurface, they form between them an angle of 32 minutes in the incidence, and afterwards in the reflection, and that, conſequently, the image muſt increaſe in ſize, in proportion as it is farther diſtant. Attention muſt likewiſe be paid to the figure of thoſe images; for example, a plain ſquare glaſs of half a foot, expoſed to the rays of the ſun, will form a ſquare image of ſix inches, when this image is received at the diſtance of a few feet; by removing farther and farther off, the image is ſeen to increaſe, afterwards to become deformed, then round, in which ſtate it remains ſtill increaſing in ſize, in proportion as we are more diſtant from the mirror. This image is compoſed of as many of the ſun's diſks as there are phyſical points in the reflecting ſurface; the middle point forms an image of the diſk, the adjoining points form the like, and of the ſame ſize, which exceed a little the middle diſk: it is the ſame with the other points, and the image is compoſed of an infinity of diſks, which ſurmounting regularly, and anticipating circularly one over the other, form the reflected image, of which the middle point of the glaſs is the centre.

If the image compoſed of all theſe diſks is received at a ſmall diſtance, then their extent being ſomewhat larger than that of the glaſs, this image is of the ſame figure, and nearly of the ſame extent as the glaſs; but when the image is received at a great diſtance from the glaſs, where the extent of the diſks is much greater than that of the glaſs, the image no longer retains the ſame figure as the glaſs, but becomes neceſſarily circular. To find the point of diſtance where the image loſes its ſquare figure, we have only to ſeek for the diſtance where the glaſs appears under an angle equal to that the ſun forms to our ſight, i. e. an angle of 32 minutes, and this diſtance will be that where the image will loſe its ſquare figure, and become round, for the diſks having always an equal line to the ſemi-circle, which meaſures an angle of 32 minutes for a diameter, we ſhall find by this rule that a ſquare glaſs of ſix inches loſes its ſquare figure at the diſtance of about 60 feet, and that a glaſs of a foot ſquare loſes it at 120 feet, and ſo on of the reſt.

By reflecting a little on this theory we ſhall no longer be aſtoniſhed to find, that at very great diſtances a large and ſmall glaſs afford nearly an image of the ſame ſize, and which only differs by the intenſity of the light; we ſhall no longer be ſurpriſed that a round, ſquare, long, or triangular glaſs, or any other figure, always yields round images*; and we ſhall evidently ſee that images do not increaſe and leſſen by the diſperſion of light, or by any loſs in paſſing thro' the air, as ſome phyſicians have imagined; but that, on the contrary, it is only occaſioned by the augmentation of the diſks, which always occupy a ſpace of 32 minutes to whatever diſtance they are removed.

So, likewiſe, we ſhall be convinced, by the expoſition of this theory, that curves, of whatſoever kind they be, cannot be uſed with advantage to burn at a diſtance, becauſe the diameter of the focus can never be ſmaller than the chord which meaſures an angle of 32 minutes, and that, conſequently, the moſt perfect concave mirror, whoſe diameter is equal to this chord, will never produce double the effect of a plain mirror of the ſame ſurface; and if the diameter of a curved mirror was leſs than the chord, it would ſcarcely have more effect than a plain mirror of the ſame ſurface.

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* This is the reaſon that the ſmall images, which paſs betwixt the leaves of high and full trees, and which falling on the walks, are all oval or round.

When I had well conſidered the above I had no longer a doubt that Archimedes could not burn at a diſtance but with plain mirrors, for, independent of the impoſſibility they then felt, and which we feel at preſent, of making concave mirrors with ſo large a focus, I perceived that the reflection I have juſt made could not have eſcaped this great mathematician. Beſides, according to every appearance, the ancients did not know how to make large maſſes of glaſs; they were ignorant of the art of burning it to make large glaſſes, poſſeſſing only the method of blowing it, and making bottles and vaſes; from which conſideration I was led to conclude, that it was with plain mirrors of poliſhed metals, and by the reflections of the ſun, that Archimedes had been enabled to burn at a diſtance. But as I perceived that glaſs mirrors reflected the light more powerfully than the moſt poliſhed mirrors, I thought to conſtruct a machine to coincide in the ſame point the reflected images by a great number of theſe plain glaſſes, being well convinced that this was the ſole mode of ſucceeding.

Nevertheleſs, I had ſtill ſome doubts remaining, which appeared to me well founded. For ſuppoſing the burning diſtance to be 240 feet, I perceived clearly that the focus of my mirror could not have a leſs than two feet diameter; in which caſe what would be the extent I ſhould be obliged to give to my aſſemblage of plain mirrors to produce a fire in ſo great a focus? It might be ſo great that the thing would be impracticable in the execution, for by comparing the diameter of the focus to the diameter of the mirror, in the beſt reflecting mirrors, I obſerved, that the diameter of the Academy's mirror, which is three feet, was 108 times bigger than its focus, which was no more than four lines, and I concluded, that to burn as ſtrong at 240 feet it was neceſſary that my aſſemblage of mirrors ſhould be 216 feet diameter to have a focus of two feet; now a mirror of 216 feet diameter was certainly an impoſſible thing.

This mirror of three feet diameter burnt ſtrong enough to melt gold, and I was deſirous to ſee how much I ſhould gain by reducing its action to the burning of wood. For this purpoſe I uſed circular zones of paper on the mirrors to diminiſh the diameter, and I found that there was no longer power enough to inflame dry wood when its diameter was reduced to little more than four inches; therefore taking five inches, or ſixty lines, for the diameter neceſſary to burn with a focus of four lines, it appeared, that to burn equally at 240 feet, where the focus ſhould neceſſarily have two feet diameter, I ſhould require a mirror of 30 feet diameter, which appeared ſtill as impoſſible, or at leaſt impracticable.

To ſuch poſitive concluſions, and which others would have regarded as demonſtrations of the impoſſibility of the mirror, I had only a ſuppoſition to oppoſe; an old ſuppoſition, on which the more I had reflected the more I was perſuaded that it was not without foundation; namely, that the effects of heat might poſſibly not be in proportion to the quantity of light, or, what amounts to the ſame, that at the equal intenſity of light large focuſes muſt burn briſker than the ſmall.

By eſtimating heat mathematically, it is not to be doubted but that the power of a focus of the ſame length is in proportion to the ſurface of the mirror. A mirror, whoſe ſurface is double that of another, muſt have the ſame ſized focus, and this focus muſt contain double the quantity of light which the firſt contained; and in the ſuppoſition, that effects are always in proportion to their cauſes, it had always been thought that the heat of this ſecond focus ſhould be double that of the firſt.

So likewiſe, and by the ſame mathematical eſtimation, it has always been thought, that at an equal intenſity of light, a ſmall focus ought to burn as much as a large one, and that the effect of the heat ought to be in proportion to this intenſity of light: *inſomuch* (ſays Deſcartes) *that glaſſes, or extremely ſmall mirrors, may be made, which will burn with as much violence as the large.* I at firſt thought that this concluſion, drawn from mathematical theory, might be found falſe in the practice, becauſe heat being a phyſical quality, of the action and propagation of which we know not the laws, it ſeemed to me, that there was ſome kind of temerity to eſtimate thus effects by a ſimple ſpeculation.

I had, therefore, once more recourſe to experiments. I took metal mirrors of different focuſes and different degrees of poliſh, and by comparing the different actions on the ſame fuſible or combuſtible matters, I found, that at an equal intenſity of light, large focuſes conſtantly have more effect than ſmall, and I diſcovered the ſame to be the caſe with refracting mirrors.

The reaſon of this difference is eaſy to be aſſigned, if we conſider, that heat communicates nearer and nearer, and diſperſes, if I may ſay ſo, when it is even applied on the ſame point: for example, if we let the focus of a burning-glaſs fall on the centre of a crown piece, and that this focus was only a 22d of an inch diameter, the heat produced on the centre diſperſes and extends over and throughout the whole piece: thus all the heat, although uſed at firſt to the centre of the crown, does not ſtop there, and conſequently cannot produce ſo great an effect as if it did. But if, inſtead of a focus of a 12th of an inch, we let fall a focus of equal intenſity on the whole crown, every part being alike heated, then inſtead of experiencing the loſs of heat, it acquires an augmentation; for the middle profiting of the heat with the other points which ſurround it, the crown piece will be melted in this latter caſe, whereas, in the firſt, it will be only ſlightly heated.

After theſe experiments and reflections, I felt the hope of my ſucceſs to make mirrors to burn at a great diſtance prodigiouſly to increaſe; for I began no longer to dread, as before, the great extent of the focus; I was perſuaded, on the contrary, that a focus of a conſiderable breadth, as two feet, and in which the intenſity of the light would not be near ſo great as in a ſmall focus of four lines, might, nevertheleſs, produce inflammation, and with more power; and that, conſequently, this mirror, which, by mathematical theory, ought to have at leaſt thirty feet diameter, would be reduced to one of eight or ten feet at moſt, which was not only a poſſible, but even a very practicable thing.

I then thought ſeriouſly to execute my project: I had at firſt a deſign of trying to burn at 200 or 300 feet diſtance with circular or hexagon glaſſes, of a ſquare foot in ſurface, and I was deſirous of having four iron carriages for them, with ſcrews to each to move them, and a ſpring to adjuſt them; but the conſiderable expence this adjuſtment exacted, made me quit that idea, and I took two common glaſſes of ſix inches by eight, and a wooden adjuſtment, which, in fact, was leſs ſolid and preciſe, but the expence was more agreeable; the mechaniſm of which I had executed by M. Paſſement.

It is ſufficient to ſay, that it was at firſt compoſed of 168 glaſſes of ſix inches by eight each, about 4-12ths of an inch diſtant from each other; theſe glaſſes moved in all directions, and the four lines of ſpace between them not only ſerved for the freedom of this motion, but alſo to let the operator ſee the place where he was to conduct his images. By means of this conſtruction, 168 images could be thrown on one point, and, conſequently, burn at ſeveral diſtances, as at 20, 30, and to 150 feet. By increaſing the ſize of the mirror, or by making other mirrors like the firſt, we are certain of throwing fire to ſtill greater diſtances, or to increaſe as much as we pleaſe the force or activity of thoſe firſt diſtances.

It is only to be obſerved, that the motion here ſpoken of is not very eaſy to be executed, and that alſo there is a very great choice to be made in the glaſſes; for they are not all equally good, though they appear ſo at the firſt inſpection. I was obliged to pick out of more than 500 the 168 I made uſe of. The method of trying them is to receive at 150 feet diſtance the reflected image of the ſun, as a vertical plane; we muſt ſelect thoſe which give a round and terminated image, and put aſide the reſt, whoſe thickneſſes being unequal in different parts, or the ſurface a little concave or convex, have images badly terminated, double, treble, oblong, &c. according to the different defects found in the glaſſes.

By the firſt experiment I made the 23d of March, 1747, at noon I ſet fire to a plank of fir at ſixty-ſix feet diſtance, with forty glaſſes only, about a quarter of the mirror. It muſt be obſerved, that not being yet mounted, it was very diſadvantageouſly placed, forming an angle with the ſun of twenty degrees declination, and another of more than ten degrees inclination.

The ſame day I ſet fire to a pitchy and ſulphureous plank at 126 feet diſtance, with eighty-eight glaſſes, the mirror being ſtill placed diſadvantageouſly. It is well known, that to burn with more advantage, the mirror ſhould be directly oppoſed to the ſun, as well as the matters to be inflamed; ſo that, by ſuppoſing a perpendicular plane on the plane of the mirror, it muſt paſs by the ſun, and, at the ſame time, through the midſt of combuſtible matters.

The 3d of April, at four o'clock in the afternoon, the mirror being mounted, produced a ſlight a ſlight inflammation on a plank covered with pitch at 138 feet diſtance, although the ſun was weak and the light pale. It is requiſite to be careful, when we approach the ſpot where the combuſtible matters are, and not look on the mirror; for if, unfortunately, the eyes ſhould meet the focus, inevitable blindneſs will enſue.

The 4th of April, at eleven in the morning, although the ſun appeared watery, and the ſky cloudy, yet it produced, with 154 glaſſes, ſo conſiderable a heat at 158 feet, that in leſs than two minutes it made a deal plank to ſmoke, and which would certainly have flamed, if the ſun had not ſuddenly diſappeared.

The enſuing day, the 5th of April, at three o'clock in the afternoon, we ſet fire in a minute and an half at 150 feet diſtance, to a plank ſulphured and mixed with coals, with 154 glaſſes. When the ſun is powerful, only a few ſeconds is required to produce inflammation.

The 10th of April in the afternoon, the ſun being bright, we ſet fire to a fir plank at 150 feet diſtance, with only 128 glaſſes: the inflammation was very ſudden, and made in all the extent of the focus, which was about ſixteen inches diameter at this diſtance.

The ſame day, at half paſt two o'clock, we threw the fire on another plank, partly pitched and covered with ſulphur in ſome places: the inflammation was made very ſuddenly; it began by the parts of the wood which were uncovered, and the fire was ſo violent, that the plank was obliged to be dipped in water to extinguiſh it: there were 148 glaſſes at 150 feet diſtance.

The 11th of April, the focus being only 20 feet diſtant from the mirror, it only required 12 glaſſes to inflame ſmall combuſtible matters; with 21 glaſſes we ſet fire to another plank which had already been partly burnt; with 45 glaſſes we melted a block of tin of 6lb. weight; and with 117 glaſſes we melted thin pieces of ſilver, and reddened an iron plate; and I am alſo perſuaded, that by uſing all the glaſſes of the mirror we ſhould have been enabled to have melted metals at 50 feet diſtance; and as the focus at this diſtance was ſix or ſeven inches broad, we ſhould be able to make trials on all metals, which it was not poſſible to do with common mirrors, whoſe focus is either very weak or 100 times ſmaller than that of mine. I have remarked, that metals, and eſpecially ſilver, ſmoke much before they melt; the ſmoke was ſo ſtriking that it ſhaded the ground, and it was there I looked on it attentively, for it is not poſſible to look a moment on the focus when it falls on the metal, the luſtre being much more dazzling than that of the ſun.

The experiments which I have here related have been followed by a great number of others, which confirm them. I have ſet fire to wood at 210 feet diſtance with this mirror, by the ſun in the ſummer; and I am certain, that with four ſimilar mirrors I could burn at 400 feet, and, perhaps, at a greater diſtance. I have, likewiſe, melted all metals, and metallic minerals, at 125, 130, and 140 feet. We ſhall find, in the courſe of this article, the uſes to which theſe mirrors can be applied, and the limits that muſt be aſſigned to their power for calcination, combuſtion, fuſion, &c.

This mirror burnt according to the different inclination given it, and what gave it this advantage over the common reflecting mirrors was, that its focus was very diſtant, and had ſo little curvature, that it was almoſt imperceptible: it was ſeven feet broad by eight feet high, which makes about 150th part of the circumference of the ſphere, when we burn at 150 feet diſtance.

The reaſon that determined me to prefer glaſſes of ſix inches broad by eight inches high, to ſquare glaſſes of ſix or eight inches, was, that it is much more commodious to make experiments upon an horizontal and level ground than otherwiſe, and that with this figure higher than broader the images were rounder; whereas with ſquare glaſſes they would be ſhortened, eſpecially at ſmall diſtances, in an horizontal ſituation.

This diſcovery furniſhes us with many uſeful hints for phyſic, and, perhaps, for the arts. We know that what renders common reflecting mirrors almoſt uſeleſs for experiments is, that they burn almoſt always upwards, and that we are greatly embarraſſed to find means to ſuppreſs or ſupport matters to be melted or calcined to their focus. By means of my mirror we burn concave mirrors downwards, and with ſo great an advantage that we have what degree of heat we pleaſe; for example, by oppoſing to my mirror a concave one of a foot ſquare in the ſurface, the heat produced to this laſt mirror, by uſing 154 glaſſes only, will be upwards of 12 times greater than that generally produced, and the effect will be the ſame as if 12 ſuns exiſted inſtead of one, or rather as if the ſun had 12 times more heat.

Secondly, By means of my mirror we ſhall have the true ſcale of the augmentation of heat, and make a real thermometer, whoſe diviſions will be no longer arbitrary, from the temperature of the air to what degree of heat we chuſe, by letting fall, ſucceſſively, the images of the ſun one on the other, and by graduating the intervals, whether by means of an expanſive liquor, or a machine of dilatation, and from that we ſhall know, in fact, what a double, treble, quadruple, &c. augmentation of heat is, and ſhall find out matters whoſe expanſion, or other effects, will be the moſt ſuitable to meaſure the augmentations of heat.

Thirdly, We ſhall exactly know how many times is required for the heat of the ſun to burn, melt, or calcine different matters, which was hitherto only known in a vague and very indefinite manner; and ſhall be in a ſtate to make preciſe compariſons of the activity of our fires with that of the ſun, and have exact relations and fixed and invariable meaſures. In ſhort, thoſe who examine my theory, and ſhall have ſeen the effect of my mirror, I think will be convinced that the mode I have uſed was the only one poſſible to ſucceed to burn far off, for, independent of the phyſical difficulty of making large concave, ſpherical, parybolical mirrors, or of any other curvature whatſoever, regular enough to burn at 150 feet diſtance, we ſhall eaſily be convinced that they would not produce but nearly as much effect as mine, becauſe the focus would be almoſt as broad; that beſides, theſe curved mirrors, if even it ſhould be poſſible to make them, would have the very great diſadvantage to burn only at a nigh diſtance, whereas mine burns at all diſtances; and, conſequently, we ſhall abandon the ſcheme of making mirrors to burn at a great diſtance by means of curves, which has uſeleſsly employed a great number of mathematicians and artiſts, who were always deceived, becauſe they conſidered the rays of the ſun as parallel, whereas they ſhould be conſidered as they are, namely, as forming angles of all ſizes, from 0 to 32 minutes, which makes it impoſſible, whatſoever curve is given to a mirror, to render the diameter of the focus ſmaller than the chord, which meaſures 32 minutes. Thus, if even we could make a concave mirror to burn at a great diſtance; for example, at 150 feet, by employing all its points on a ſphere of 600 feet diameter, and by employing an uncommon maſs of glaſs or metal, it is evident that we ſhall have a little more advantage than by uſing, as I have done, only ſmall plain mirrors.

On the whole, altho' this mirror is ſuſceptible of a very great perfection, both for the adjuſtment, and many other particulars, and tho' I think I ſhall be able to make another, whoſe effects will be ſuperior, yet, as every thing has its limits, it muſt not be expected that ever one can be formed to burn at extreme diſtances; to burn, for example, at the diſtance of half a mile, a mirror 200 times larger would be required; and I am of opinion that more will never be effected than to burn at the diſtance of 8 or 900 feet. The focus, whoſe motion is always correſpondent to that of the ſun, moves ſo much the quicker, as it is farther diſtant from the mirror; and at 90 feet it would move about ſix feet a minute.

However, as I have given an account of my diſcovery, and the ſucceſs of my experiments, I ſhould render to Archimedes, and the ancients, the glory that is their due. It is certain that Archimedes could perform with metal mirrors what I have done with glaſs, and that, conſequently, I cannot refuſe him the title of the firſt inventor of theſe mirrors, which the opportunity he had to uſe them rendered him, without doubt, more celebrated than the merit of the thing itſelf.

Many advantages may be derived from the uſe of theſe mirrors; with an aſſemblage of ſmall mirrors, with hexagonal planes, and poliſhed ſteel, which will have more ſolidity than glaſſes, and which would not be ſubject to the alterations which the light of the ſun may cauſe, we may produce very uſeful effects, and which would amply repay the expences of the conſtruction of the mirror.

1. For all evaporations of ſalt waters, where great quantities of wood and coal are conſumed, or ſtructures for the purpoſe of carrying the waters off, which coſt more than the conſtruction of many mirrors, ſuch as I mention; for the evaporation of ſalt waters, only an aſſemblage of twelve plain mirrors of a ſquare foot each is neceſſary. The heat reflected by their focuſes, although directed below their level, and at fifteen or ſixteen feet diſtance, will be ſtill great enough to boil water, and conſequently, produce a quick evaporation; for the heat of boiling water is only treble the heat of the ſun in ſummer; and as the reflection of a well poliſhed plain ſurface only diminiſhes the heat one half, ſix mirrors are only required to produce to the focus a heat equal to boiling

water; but I ſhall double the number to make the heat communicate quicker; and likewiſe by reaſon of the loſs occaſioned by the obliquity, under which the light falls on the ſurface of the water to be evaporated, and becauſe ſalt water heats ſlower than freſh. This mirror, whoſe aſſemblage would form only a ſquare four feet broad by three feet high, would be eaſy to be managed; and if it were required to double or treble the effects in the ſame time, it would be better to make ſo many ſimilar mirrors, than to augment the ſtate of them; for water can only receive a certain quantity of heat, and we ſhould not gain any thing by increaſing this degree; whereas, by making two focuſes with two equal mirrors, we ſhould double the effect of the evaporation, and treble it by three mirrors, whoſe focuſes would fall ſeparately one from the other on the ſurface of the water to be evaporated. We cannot avoid the loſs cauſed by the obliquity; nor can it be remedied but by ſuffering a ſtill greater, that is, by receiving the rays of the ſun on a large glaſs which would reflect them broken on the mirror; for then it would burn at bottom inſtead of the top, but it would loſe half the heat by the firſt reflection, and half of the remainder by the ſecond: ſo that inſtead of ſix ſmall mirrors, it would require a dozen to obtain a heat equal to boiling water. For the evaporation to be made with more ſuccefs, we ought to diminiſh the thicknefs of the water as much as poſſible; a maſs of water a foot deep will not evaporate nearly ſo quick as the ſame maſs reduced to ſix inches, and increaſed to double the ſuperficies. Beſides, the bottom being nearer the ſurface, it heats quicker, and this heat, which the bottom of the veſſel receives, contributes ſtill more to the celerity of the evaporation.

2. Theſe mirrors may be uſed with advantage to calcine plaiſters, and even calcareous ſtones, but they would require to be larger, and the matters placed in an elevated ſituation, that nothing may be loſt by the obliquity of the light. It has already been obſerved that gypſums heat as ſoon again as ſoft calcareous ſtone, and nearly twice as quick as marble, or hard calcareous ſtone; their calcination, therefore, muſt be in a reſpective ratio. I have found by an experiment repeated three times, that very little more heat is required to calcine white gypſum, called alabaſter, than to melt lead. Now the heat neceſſary to melt lead is, according to Newton, eight times ſtronger than the heat of the ſummer ſun; it therefore would

require ſixteen ſmall mirrors to calcine gypſum; and becauſe of the loſſes thereby occaſioned, as well as by the obliquity of the light, and the inequality of the focus, that is not removed above fifteen feet, I preſume it would require twenty, and perhaps twenty-four mirrors of a foot ſquare each, to calcine gypſum in a ſhort time, conſequently it would require an aſſemblage of forty-eight ſmall mirrors to calcine the ſofteſt calcareous ſtone, and ſeventy-two of a foot ſquare to calcine hard calcareous ſtones. Now a mirror twelve feet broad by ſix feet high, would be a large and cumberſome machine; nevertheleſs, we might conquer theſe difficulties if the product of the calcination was conſiderable enough to be equivalent, and to ſurpaſs the expence of the conſumption of wood. To aſcertain this, we ought to begin with calcining of plaiſter with a mirror of twenty-four pieces, and if that ſucceeded, to make two other like mirrors, inſtead of making a large one of ſeventy-two pieces; for by co-inciding the focuſes of theſe three mirrors of twenty-four pieces, we ſhall produce an equal heat, ſtrong enough to calcine marble or hard ſtone.

But a very eſſential matter remains doubtful, that is, to know how long time would be requiſite to calcine a cubical foot of matter, eſpecially if that foot was ſtruck with the heat only in one part. Some time would paſs before the heat penetrated its thickneſs; during this time, a great part of the heat would be loſt, and which would iſſue from this piece of matter after it had entered therein. I greatly doubt, therefore, whether the ſtone not being touched by the heat on every ſide at once, the calcination would not be ſlower, and the produce leſs. Experience alone can decide this, but it would be at leaſt neceſſary to attempt it on gypſous matters, whoſe calcination is as quick again as calcareous ſtone.

By concentrating this heat of the ſun in a kiln, which has no other opening than that which admits the light, a great part of the heat would be prevented from flying off, and by mixing with calcareous ſtone a ſmall quantity of coal duſt, which is the cheapeſt of all combuſtible matters, this ſlight ſupply of food would ſuffice to feed and augment the quantity of heat, which would produce a more ample and quick calcination, and at very little expence.

3. Theſe mirrors of Archimedes might be, in fact, uſed to ſet fire to the ſails of veſſels, and even to pitched wood at more than 150 feet

diſtance; they might alſo be uſed againſt the enemy, by burning the grain and other productions of the earth; this effect would be no leſs ſudden than deſtructive; but we ſhall not dwell on the means of doing miſchief, conceiving it to be more our duty to think on thoſe which may do ſome real ſervice to human nature.

4. Theſe mirrors furniſh the ſole means of exactly meaſuring heat. It is evident, that two mirrors, whoſe luminous images unite, produce double heat in all the points of their ſurfaces, that three, four, five, or more mirrors, will alſo give a treble, quadruple, quintuple, &c. heat, and that, conſequently, by this mode we can make a thermometer whoſe diviſions will not be too arbitrary, and the ſcales different, like thoſe of the preſent thermometers. The only arbitrary thing which would enter into the compoſition of this thermometer, would be the ſuppoſition of the total number of the parts of the quickſilver by quitting the degree of abſolute cold; but by taking it to 10000 below the congelation of water, inſtead of 1000, as in our common thermometers, we ſhould approach greatly towards reality, eſpecially by chuſing the coldeſt day in winter to mark the thermometers, for then every image of the ſun

would give it a degree of heat above the temperature of ice. The point to which the mercury riſes by the firſt image of the ſun, would be marked 1, and ſo on to the higheſt, which might be extended to 36 degrees. At this degree we ſhould have an augmentation of heat, thirty-ſix times greater than that of the firſt, eighteen times greater than the ſecond, twelve times greater than the third, nine times greater than the fourth, and ſo on; this augmentation of thirty-ſix of heat above that of ice would be ſufficient to melt lead; and there is every appearance to think that mercury, which volatilizes by a much leſs heat, would by its vapour break the thermometer. We cannot, therefore, at moſt extend the diviſion farther than twelve, and perhaps not farther than nine degrees, if mercury is uſed for theſe thermometers, and by theſe means we ſhall have only nine degrees of the augmentation of heat. This is one of the reaſons which induced Newton to make uſe of linſeed oil inſtead of quickſilver; and, in fact, we can, by making uſe of this liquor, extend the diviſion not only to twelve degrees, but as far as to make this oil to boil. I do not propoſe ſpirits of wine, becauſe that liquor decompoſes in a very ſhort time, and cannot be uſed for experiments of a ſtrong heat.

When on the ſcale of theſe thermometers filled with oil or mercury, the firſt diviſions 1, 2, 3, 4, &c. are marked to indicate the double, treble, quadruple, &c. augmentations of heat, we muſt ſearch after the aliquot parts of each diviſion; for example, of the point $1\frac{1}{4}$, $2\frac{1}{4}$, $3\frac{1}{4}$, &c. or $1\frac{1}{2}$, $2\frac{1}{2}$, $3\frac{1}{2}$, &c. and $1\frac{3}{4}$, $2\frac{3}{4}$, $3\frac{3}{4}$, and which will be obtained in an eaſy manner, by covering the $\frac{1}{4}$, $\frac{1}{2}$, or $\frac{3}{4}$ of the ſuperficies of one of thoſe ſmall mirrors; for then the image which it reflects, will contain only the $\frac{1}{4}$, $\frac{1}{2}$, or $\frac{3}{4}$ of the heat which the whole image will contain, and, conſequently, the diviſion of the aliquot parts will be as exact as thoſe of the whole numbers.

If once we ſucceed in this real thermometer, which I call real, becauſe it actually marks the proportion of the heat, every other thermometer whoſe ſcale is arbitrary and different, will become not only ſuperfluous, but even hurtful in many caſes, to the preciſion of phyſical truths ſought after by their means.

5. By means of three mirrors we may eaſily collect in their purity, the volatile parts of gold, ſilver, and other metals and minerals; for, by expoſing to the large focus of thoſe mirrors a large piece of metal, as a diſh, or ſilver plate, we ſhall ſee ſmoke iſſue therefrom in great

abundance, and for a conſiderable time, till the metal is in fuſion; and by giving only a ſmaller heat than what fuſion requires, we ſhall evaporate the metal ſo as to diminiſh the weight conſiderably.

I am certain of this circumſtance, which furniſhes lights on the intimate compoſition of metals. I was deſirous of collecting this plentiful vapour, which the pure fire of the ſun cauſes to iſſue from the metal, but I had not neceſſary inſtruments, and I can only recommend to chemiſts and phyſicians to follow this important experiment, the reſults of which would be as much leſs equivocal as the metallic vapour is pure; whereas, in all like operations made with common fire, the metallic vapour is neceſſarily mixed with other vapours proceeding from combuſtible matters which ſerve for food to this fire.

Beſides, this means is the only one we have to volatilize fixed metals, ſuch as gold and ſilver; for I preſume that this vapour, which I have ſeen riſe in ſuch great quantities from theſe fixed metals, heated in the large focus of my mirror, is neither of water, nor of any other liquor, but of the parts even of the metal which the heat detaches by volatilizing them. By receiving theſe vapours of different metals, and thus mixing them together, more intimate and pure alloys would be made than can be by fuſion, and the mixture of theſe metals when melted, which never perfectly unite, by reaſon of the inequality of their ſpecific weight, and many other circumſtances which are oppoſed to the intimate and perfect equality of the mixture. As the conſtituent parts of theſe metallic vapours are in a much greater ſtate of diviſion than fuſion, they would join and unite cloſer and more readily. In ſhort, we ſhould attain the knowledge of a general fact by this mode, and which, for many reaſons, I have a long time ſuſpected, that there is penetration in all alloys made in this manner, and that their ſpecific weight would be always greater than the ſum of the ſpecific weights of the matters of which they are compoſed: for penetration is only a greater degree of intimacy, every thing equal in other reſpects will be ſo much the greater as matters will be in a more perfect ſtate of diviſion.

By reflecting on the veſſels uſed to receive and collect theſe metallic vapours, I was furniſhed with an idea, which appeared to me to be of too great utility not to publiſh; it is alſo eaſy enough to be realized by good able chemiſts; I have even communicated it to ſome

of

of them, who appeared quite ſatisfied therewith. This idea is to freeze mercury in this climate, and with a much leſs degree of cold than that of the experiments of Peterſburgh or Siberia. For this purpoſe the vapour of mercury is only required to be received, and which is the mercury itſelf volatilized by a very moderate heat in a crucible, or veſſel, to which we give a certain degree of artificial cold. This vapour, or this mercury, minutely divided, will offer, to the action of the cold, ſurfaces ſo large, and maſſes ſo ſmall, that inſtead of 187 degrees of cold requiſite to freeze mercury, poſſibly 18 or 20 will be ſufficient, and perhaps even leſs to freeze it when in vapour. I recommend this important experiment to all thoſe who endeavour earneſtly for the advancement of the ſciences.

To theſe principal uſes of the mirror of Archimedes, I could add many other particular ones; but I have confined myſelf to thoſe only which have appeared the moſt uſeful, and leaſt difficult to be put in practice; nevertheleſs I have ſubjoined ſome experiments that I made on the tranſmiſſion of light through tranſparent bodies, to give ſome new ideas on the means of ſeeing objects at a diſtance with the naked eye, or with a mirror, like that ſpoken of by the ancients,

cients, and by the effect of which veſſels could be perceived from the port of Alexandria, as far as the curvature of the earth would permit.

Phyſicians at preſent know, that there are three cauſes which prevent the light from uniting in a point, when its rays have paſſed the objective glaſs of a common mirror. The firſt is the ſpherical curve of this glaſs, which diſperſes a part of the rays in a ſpace terminated by a curve. The ſecond is the angle under which the object appears to the naked eye; for the breadth of the focus of the objective glaſs has a diameter nearly equal to the chord of which this angle meaſures. The third is the different refrangibility of the light; for the moſt refrangible rays do not collect in the ſame place with the leſſer.

The firſt cauſe may be remedied by ſubſtituting, as Deſcartes has propoſed, elliptical, or hyperbolical, glaſſes to the ſpherical. The ſecond is to be remedied by a ſecond glaſs, placed to the focus of the objective, whoſe diameter is nearly equal the breadth of this focus, and whoſe ſurface is worked on a ſphere of a very ſhort ray. The third has been found to be remedied, by making teleſcopes, called Acromatics, which are compoſed of two ſorts of glaſſes, which diſperſe the coloured rays differently; ſo that the diſperſion of the one is corrected by the other, without the general refraction, which conſtitutes the mirror, being deſtroyed. A teleſcope 3½ feet long, made on this principle, is in effect equivalent to the old teleſcopes of 25 feet.

But the remedy of the firſt cauſe is perfectly uſeleſs at this time, becauſe the effect of the laſt being much more conſiderable, has ſuch great influence on the whole effect that nothing can be gained by ſubſtituting hyperbolical, or elliptical glaſſes to ſpherical, and this ſubſtitution could not become advantageous but in the caſe where the means of correcting the effect of the different refrangibility of the rays of light might be found; it ſeems, therefore, that we ſhould do well to combine the two means, and to ſubſtitute, in acromatic teleſcopes, elliptical glaſſes.

To render this more obvious, let us ſuppoſe the object obſerved to be a luminous point without extent, as a fixed ſtar is to us. It is certain, that with an objective glaſs, for example, of 30 feet focus, all the images of this luminous point will extend in the form of a curve to this focus, if it is worked on a ſphere; and, on the contrary, they will unite in one point if this glaſs is hyperbolical; but if the object obſerved at a certain extent, as the moon, which occupies half a degree of ſpace to our eyes, then the image of this object will occupy a ſpace of three inches diameter in the focus of the objective glaſs of 30 feet ; and the abercation cauſed by the ſphericity producing a confuſion in any luminous point, it produces the ſame on every luminous point of the moon's diſk, and, conſequently, wholly disfigures it. There would be, then, much diſadvantage in making uſe of elliptical glaſſes for long teleſcopes, ſince the means has been found, in a great meaſure, to correct the effect produced by the different refrangibility of the mirrors.

From this it follows, that if we would make a teleſcope of 30 feet, to obſerve the moon and ſee it completely, the ocular glaſs muſt be at leaſt three inches diameter, to collect the whole image which the objective glaſs produces to its focus; and if we would obſerve this planet with a teleſcope of 60 feet, the ocular glaſs muſt be at leaſt ſix inches diameter, becauſe the chord which the angle meaſures under which the moon appears to us, is, in this caſe, nearly ſix inches ; therefore aſtronomers never make uſe of teleſcopes that include the whole diſk of the moon, becauſe they would magnify but very little. But if we would obſerve the planet Venus with a teleſcope of 60 feet, as the angle under which it appears to us is only 60 ſeconds, the ocular glaſs can only have four lines diameter; and if we make uſe of an objective of 120 feet, an ocular glaſs of eight lines diameter would ſuffice to unite the whole image which the objective forms to its focus.

Hence we ſee, that if even the rays of light were equally refrangible we could not make ſuch ſtrong teleſcopes to ſee the moon with as to ſee the other planets, and that the ſmaller a planet appears to our ſight the more we can augment the length of the teleſcope, with which we can ſee it wholly. Hence it may be well conceived, that in this ſuppoſition of the rays, equally refrangible, there muſt be a certain length more advantageouſly determined than any other for each different planet, and that this length of the teleſcopes not only depends on the angle under which the planet appears to our ſight, but alſo on the quantity of light with which it is brightened.

In common teleſcopes the rays of light being differently refrangible, all that could be done in this mode to perfectionate them would be of very little advantage, becauſe, that under whatſoever angle the object, or planet, appears to our ſight, and whatever intenſity of light it may have, the rays will never collect in the ſame part; the longer the teleſcope the more interval it will have between the focus of the red and violet rays, and conſequently the more confuſed the image of the object obſerved.

Refracting teleſcopes, therefore, can only be perfectionated by ſeeking for the means of correcting this effect of the different refrangibility, either by compoſing teleſcopes of different denſities, or by other particular means, which would be different according to different objects and circumſtances. Suppoſe, for example, a ſhort teleſcope, compoſed of two glaſſes, one convex and the other concave, it is certain that this teleſcope can reduce itſelf to another whoſe two glaſſes would be plain on one ſide and on the other bordering on ſpheres, whoſe rays would be ſhorter than that on the ſpheres on which the glaſſes of the firſt teleſcopes have been conſtructed. To avoid this, which conſtitutes a great part of the effect of the different refrangibility of the rays, the ſecond teleſcope may be made with one ſingle piece of maſſive glaſs, as I had it done with two pieces of white glaſs, one of two inches and an half in length, and the other one inch and an half, but then the loſs of tranſparency is a greater inconvenience than the different refrangibility which it corrects, for theſe two ſmall maſſive teleſcopes of glaſs, are more obſcure than a ſmall common teleſcope of the ſame glaſs and dimenſions; they indeed give leſs iris, but are not better, for in maſſive glaſs the light, after having croſſed this thickneſs of glaſs, would no longer have a ſufficient force to take in the image of the object to our eye. So to make teleſcopes 10 or 20 feet long I only find water that has ſufficient tranſparency to ſuffer the light to paſs through this great thickneſs. By uſing, therefore, water to fill up the intervals between the objective and the ocular glaſs, we ſhould in part diminiſh the effect of the different refrangibility, becauſe that water approaches nearer to glaſs than air, and if we could, by loading the water with different ſalts, give it the ſame refringent degree of power as glaſs, it is not to be doubted, that we ſhould correct ſtill more, by this means, the different refrangibility of the rays. A tranſparent liquor ſhould, therefore, be uſed, which would have nearly the ſame refrangible power as glaſs, for then it would be certain that the two glaſſes, with their liquor between them, would in part correct the effect of the different refrangibility of the rays, in the ſame mode as it is correcled in the ſmall maſſive teleſcope which I ſpeak of.

According to the experiments of M. Bouguer, the thickneſs of a line of glaſs deſtroys $\frac{2}{7}$ of light, and conſequently the diminution would be made in the following proportion:

Thickneſs, 1, 2, 3, 4, 5, 6 times
Diminution, $\frac{2}{7}$ $\frac{10}{47}$ $\frac{50}{343}$ $\frac{250}{2401}$ $\frac{1250}{16807}$ $\frac{6250}{117649}$

So that by the ſum of theſe ſix terms we ſhould find, that the light which paſſes through ſix lines of glaſs would loſe $\frac{102034}{117049}$, that is, about $\frac{10}{11}$ of its quantity. But it muſt be conſidered, that M. Bouguer makes uſe of glaſſes which are but little tranſparent, ſince he has obſerved, that the thickneſs of a line of theſe glaſſes deſtroys $\frac{2}{7}$ of the light. By the experiments which I have made on different kinds of white glaſs, it has appeared to me that the light diminiſhes much leſs. Theſe experiments are eaſy to be made, and what all the world may repeat.

In a dark chamber, whoſe walls were blackened, and which I made uſe of for optical experiments, I had a candle lighted of ſixes to the pound, the room was very large, and the candle the only light in it; I then tried at what diſtance I could read by this light, and found that I read very eaſily at 24 feet four inches from the candle. Afterwards, having placed a piece of glaſs, about a line thick, before it, at two inches diſtance, I found that I ſtill read very plainly at 22 feet nine inches; and by ſubſtituting to this glaſs another piece of two lines in thickneſs, and of the ſame glaſs, I read at 21 feet diſtance from the candle. Two of the ſame glaſſes joined one to the other, and placed before the candle, diminiſhed the light ſo much that I could only read at $17\frac{1}{2}$ feet diſtance; and at length, with three glaſſes, I could only read at 15 feet. Now the light of a candle diminiſhing as the ſquare of the diſtance augments, its diminution ſhould have been in the following progreſſion, if glaſſes had not been interpoſed: 2—$24\frac{1}{3}$. 2—$22\frac{3}{4}$. 2—21. 2—$17\frac{1}{2}$. 2—15, or $592\frac{1}{9}$. $517\frac{9}{16}$ 441. $306\frac{1}{4}$. 225. Therefore the loſs of the light, by the interpoſition of the glaſſes, is in the following progreſſion: $84\frac{79}{144}$. 151. $285\frac{7}{9}$. $367\frac{1}{4}$.

From hence it may be concluded, that the thickneſs of a line of this glaſs diminiſhes only $\frac{84}{592}$ of light, or about $\frac{1}{7}$; that two lines diminiſhes $\frac{157}{592}$, not quite $\frac{1}{4}$, and three glaſſes of two lines, $\frac{397}{592}$, i. e. leſs than $\frac{2}{3}$.

As this reſult is very different from that of M. Bouguer, and as I was cautious of ſuſpecting the truth of his experiments, I repeated mine with common glaſs. For long teleſcopes water can alone be uſed ; and it is ſtill to be feared that an inconveniency will ſubſiſt, from the opacity reſulting from the quantity of liquor whic fills the interval between the two glaſſes.

The longer the teleſcope the greater loſs of light will enſue ; ſo that it appears at firſt ſight that this mode cannot be uſed, eſpecially for long teleſcopes ; for following what M. Bouguer ſays in his Optical Eſſay, on the gradation of light, nine feet ſeven inches ſea-water diminiſhes the light in a relation of 14 to 5 ; therefore theſe long teleſcopes, filled with water, cannot be uſed for obſerving the ſun, and the ſtars would not have light enough to be perceived acroſs a thickneſs of 20 or 30 feet of intermediate liquor.

Nevertheleſs, if we conſider, that by allowing only an inch, or an inch and an half, for the bore of an objective of 30 feet, we ſhall very diſtinctly perceive the planets in the common teleſcopes of this length ; we may ſuppoſe, that by allowing a greater diameter to the objective we ſhould augment the quantity of light in the ratio of the ſquare of this diameter, and, conſequently, if an inch bore ſuffices to ſee a ſtar diſtinctly, in a common teleſcope,

three

three inches bore would be ſufficient to ſee it diſtinctly through a thickneſs of 10 feet water, and that with a glaſs of three inches diameter, we ſhould equally ſee it through a thickneſs of 20 feet water, and ſo on. It appears, therefore, that we might hope to meet with ſucceſs in conſtructing a teleſcope on theſe principles; for, by increaſing the diameter of the objective, we partly regain the light loſt by the defect of the tranſparency of the liquor.

But it appears to me certain, that a teleſcope conſtructed on this mode, would be very uſeful to obſerve the ſun; for, by ſuppoſing it even the length of 100 feet, the light of that luminary would not be too ſtrong after having traverſed this thickneſs of water, and we ſhould be enabled to obſerve its ſurface eaſily, and at leiſure, without the need of making uſe of ſmoked glaſſes, or of receiving the image on paſteboard; an advantage we cannot poſſibly derive from any other teleſcope.

There would require only ſome trifling difference in the conſtruction of this ſolar teleſcope, if we wanted the whole face of the ſun preſented; for, ſuppoſing it the length of 100 feet, in this caſe, the ocular glaſs muſt be ten inches diameter; becauſe the ſun, taking up more than half a celeſtial degree, the image formed by the objective to its focus at 100 feet, will at leaſt have this length of ten inches; and to unite it wholly, it will require an ocular glaſs of this breadth, to which only twenty inches of focus ſhould be given to render it as ſtrong as poſſible. It is neceſſary that the objective, as well as the ocular glaſs, ſhould be ten inches diameter, in order that the image of the ſun, and the image of the bore of the teleſcope, ſhould be of an equal ſize with the focus.

If this teleſcope, which I propoſe, ſhould only ſerve to obſerve the ſun exactly, it would be of great ſervice: for example, it would be very curious to be able to diſcover whether there are any luminous parts larger than others in the ſun; if there are inequalities on its ſurface, and of what kind; if the ſpots float on its ſurface; or whether they are fixed there, &c. The brightneſs of its light prevents us from obſerving this luminary with the naked eye, and the different refrangibility of its rays renders its image confuſed when received in the focus of an objective glaſs, or on paſteboard, ſo that the ſurface of the ſun is leſs known to us, than that of any of the planets. The different refrangibility of its rays would not be nearly corrected in this long teleſcope filled with water; but if the liquor could, by the addition of ſalts, be rendered as denſe as glaſs, it would then be the ſame as if there was only one glaſs to paſs through; and it appears to me that infinitely more advantage would reſult from making uſe of theſe teleſcopes filled with water, than from the common teleſcopes with ſmoked glaſſes.

Whether that would or would not be the fact, this however is certain, that to obſerve the ſun, a teleſcope is required quite different from thoſe we make uſe of for the different planets; and it is alſo certain, that a particular teleſcope is neceſſary for each planet, proportionate to their intenſity of light, that is, to the real quantity of light with which they appear to be enlightened. In all teleſcopes the objectives are required as large, and the ocular glaſs as ſtrong, as poſſible, and, at the ſame time, the diſtance of the focus proportionated to the intenſity of the light of each planet. To do this with the greateſt advantage, it is requiſite to uſe only an objective glaſs ſo much the larger, and a focus ſo much the ſhorter as the planet has light. Why has there not hitherto objective glaſſes been made of 243 feet diameter? The aberration of the rays, occaſioned by the ſphericity of the glaſſes, is the ſole cauſe of the confuſion, which is as the ſquare of the diameter of the tube; and it is for this reaſon that ſpherical glaſſes, with a ſmall bore, are of no value when enlarged; we have more light, but leſs diſtinction and clearneſs. Neverthel eſs, broad ſperical glaſſes are very good for night teleſcopes. The Engliſh have conſtructed teleſcopes of this nature, and they make uſe of them very advantageouſly to ſee veſſels at a great diſtance in dark nights. But at preſent, as we know how, in a great meaſure, to correct the effects of the different refrangibility of the rays, it ſeems, that we ſhould make elliptical or hyperbolical glaſſes, which would not produce the alteration cauſed by ſphericity, and which, conſequently, would be three or four times broader than ſpherical glaſſes. There is only this mode of augmenting to our ſight the quantity of light ſent to us from the planets, for we cannot put an additional light on them, as we do on objects we obſerve with the microſcope, but muſt at leaſt employ to the greateſt poſſible advantage, the quantity of light with which they are illumined, by receiving it on as great a ſurface as poſſible. This hyperbolical teleſcope, which would be compoſed only of one ſingle large objective glaſs, and of an ocular one proportionate, would require matter of the greateſt tranſparency; and we ſhould unite by this means all the advantages poſſible, that is, thoſe of the acromatic to that of the elliptical or hyperbolical teleſcopes, and we ſhould profit of all the quantity of light each planet reflects to our ſight. I may be deceived, but what I propoſe appears to be ſufficiently founded to recommend its execution to perſons zealouſly attached to the advancement of the ſciences.

Employing myſelf thus on theſe reveries, ſome of which may one day be realized, and on which hope I publiſh them, I thought of the Alexandrian mirror, ſpoken of by ſome ancient authors, and by means of which veſſels were ſeen at a great diſtance on the ſea. The moſt poſitive paſſage I met with is the following:

"Alexandria .... in Pharo vero erat ſpeculum e ferro ſinico. Per quod a longe videbantur naves Græcorum advenientes; ſed paulo poſtquam Iſlamiſmus invaluit, ſcilicet tempore califatus Walidfil: Abdi-l-melec, Chriſtiani, fraude adhibita illud deleverunt. Abu-l-feda, &c. Deſcriptio Ægypti."

Having dwelt for ſome time thereon, I have been led to conclude, 1. That ſuch a mirror was poſſible to be made. 2. That even without a mirror or teleſcope, we might by certain diſpoſitions obtain the ſame effect, and ſee veſſels from land, as far, perhaps, as the curvature of the earth would permit. We have before obſerved that perſons whoſe ſight was very good, have perceived objects illumined by the ſun, at more than 3400 times their diameter, and at the ſame time we have remarked, that the intermediate light was of ſuch great hurt to that of diſtant objects, that by night a luminous object is perceived at ten, twenty, and perhaps a hundred times greater diſtance than during the day. We know that at the bottom of very deep pits, ſtars may be ſeen in the day-time; why therefore, ſhould we not ſee veſſels illumined by the rays of the ſun, by placing one's ſelf at the end of a very long dark gallery, ſituated on the ſea ſhore, in ſuch a manner as to receive no other light than that of the diſtant ſea, and the veſſels which might be thereon? This gallery would be only an horizontal pit, which would have the ſame effect with reſpect to ſhips as the vertical pit has with reſpect to the ſtars; and it appears to me ſo ſimple, that I am aſtoniſhed it has never before been thought of and tried. It ſeems to me, that by taking the time of the day for our obſervations when the ſun ſhould be behind the gallery, we might ſee them from the dark end of it ten times at leaſt better than in the open light. Now a man on horſeback is eaſily diſtinguiſhed at a mile diſtance, when the rays of the ſun ſhine on him, and by ſuppreſſing the intermediate light which ſurrounds us, and darkening our ſight, we ſhould ſee him at leaſt ten times farther; that is to ſay, 10 miles. Ships, therefore, being much larger, would be ſeen as far as the curvature of the earth would permit, without any other inſtrument than the naked eye.

But a concave mirror, of a great diameter, and any focus, placed at the end of a long black tube, would have nearly the ſame effect as our great objective glaſſes of the ſame diameter and form would have during the night, and it was probably one of theſe concave mirrors of poliſhed ſteel that was eſtabliſhed at the port of Alexandria. If this ſteel mirror did really exiſt we cannot refuſe to the ancients the glory of the firſt invention, for this mirror can be only effected by as much as the light reflected by its ſurface was collected by another concave mirror placed at its focus, and in this conſiſts the eſſence of the teleſcope and the merit of its conſtruction. Nevertheleſs, this does not deprive Newton of any glory, who firſt renewed the almoſt-forgotten invention. As the rays of light are by their nature differently refrangible, he was inclined to think there were no means of correcting this effect, or, if he had perceived thoſe means, he judged them ſo difficult that he choſe rather to turn his views another way, and produce, by means of the reflection of the rays, the great effects which he could not obtain by their refraction; he, therefore, conſtructed his teleſcope, the reflection of which is infinitely ſuperior to thoſe that were in common. The beſt teleſcopes are always dark in compariſon of the acromatic, and this obſcurity does not proceed only from the defect of the poliſh, or the colour of the metal of mirrors, but from the nature even of light, the rays of which being differently refrangible are alſo differently reflexible, although in much leſs unequal degrees.

It ſtill remains, therefore, to bring the teleſcope to perfection, and to find the manner of compenſating this different reflexibility, as we have diſcovered that of compenſating the different refrangibility.

After all, I imagine that it will be well perceived that a very good day-glaſs may be made, without uſing either glaſſes or mirrors, and ſimply by ſuppreſſing the ſurrounding light, by means of a tube 150 or 250 feet long, and by placing ourſelves in an obſcure place. The brighter the day is, the greater will be the effect. I am perſuaded that we ſhould be able to ſee at 15, and perhaps 20 miles diſtance. The only difference between this long tube and the dark gallery, which I propoſed, is, that the field, or the ſpace ſeen, would be ſmaller, and preciſely in the ratio of the ſquare of the bore of the tube to that of the gallery.

OBSERVATIONS AND EXPERIMENTS ON TREES AND OTHER VEGETABLES.

THE phyſical ſtudy of Vegetables is one of thoſe ſciences which require a multiplicity of obſervations and experiments beyond the capacity of one man, and muſt conſequently be a work of time; even the obſervations are ſeldom of much value till they have been repeatedly made, and compared in different places and ſeaſons, and by different perſons of ſimilar ideas. It was in this view that M. Buffon united with M. Du Hamel, to labour in concert for the eclairciſſement of a number of phenomena, which appeared difficult to explain, in the vegetable kingdom, and from the knowledge of which may reſult an infinity of uſeful matters in the practice of agriculture.

The froſt is ſometimes ſo intenſe during winter that it deſtroys almoſt all vegetables, and the ſcarcity in the year 1709 was a melancholy proof of its cruel effects. Seeds, and ſome kinds of trees, entirely periſhed, while others, as olives, and almoſt all fruit-trees, ſhared a milder fate, ſhooting forth their leaves, their roots not having been hurt ; and many large trees, which were more vigorous, ſhot forth every branch in ſpring, and did not appear to have ſuffered any material injury. We ſhall, neverthelefs, remark on the real and irreparable damage this winter occaſioned them.

Froſt, which can deprive us of the moſt neceſſary articles of life, deſtroy many kinds of uſeful trees, and ſcarcely ever leaves one inſenſible of its rigour, is certainly one of the moſt formidable misfortunes of human nature ; therefore we have every reaſon to dread from intenſe froſts, which might reduce us to the laſt extremities if their ſeverities were frequent ; but fortunately we can quote only two or three winters which have produced ſo great and general a calamity as that in 1709.

The greateſt ſpring froſts, although they damage the grain, and principally barley, when it is but juſt eared, never occaſion great ſcarcities. They do not affect the trunks or branches of trees, but they totally deſtroy their productions, deprive us of the harveſt of the vines and orchards, and by the ſuppreſſion of new buds cauſe a conſiderable damage to foreſts.

Although there are ſome examples of winter froſts having reduced us to a ſcarcity of bread, and deprived us of vegetables, the damage which ſpring froſts occaſion becomes ſtill more important, becauſe they afflict us more frequent, and their effects are felt almoſt every year.

To conſider froſt, even very ſuperficially, we muſt perceive that the effects produced by the ſharp froſts of winter are very different from what are occaſioned by thoſe in ſpring, ſince the one attacks the body and moſt ſolid part of trees, whereas the other ſimply deſtroys their productions, and oppoſes their growth; at the ſame time they act under quite different circumſtances; and it is not always the ground in which the winter froſts produce the greateſt diſorders, as that generally ſuffers moſt from thoſe in the ſpring froſts.

It was from a great number of obſervations that we have been able to make this diſtinction of the effects of froſts, and which we hope will not be ſimply curious, but prove of utility, and be profitable to agriculture, and that if they do not wholly put us in a method of eſcaping from the evils occaſioned by froſt, they will afford a means to guard againſt them. We ſhall, therefore, enter upon the detail, beginning with that which regards the ſharp froſts of winter: of theſe, however, we cannot reaſon with ſo great a certainty as on thoſe of ſpring, becauſe, as we have already obſerved, we are ſeldom ſubjected to their tragical effects.

Moſt trees during winter being deprived of bloſſoms, fruits, and leaves, have generally their buds hardened in a ſtate of ſupporting very ſharp froſts, unleſs the preceding ſummer was cool, in which caſe the buds not being arrived to that degree of maturity, which gardeners call *aoutes* *, they are not in a ſtate of reſiſting the moderate froſts of winter; but this ſeldom happens, the buds commonly ripening before winter, and the trees endure the rigour of that ſeaſon without being damaged, unleſs exceſſive cold weather enſues, joined to the circumſtances hereafter mentioned.

We have, nevertheleſs, met with many trees in foreſts with conſiderable defects, certainly produced by the ſharp froſts, and which will never be effaced.

Theſe defects are, 1ſt, chaps or chinks, which follow the direction of the fibres. 2. A portion of dead wood included in the good; and laſtly, the double ſap, which is an entire crown of imperfect wood. We muſt dwell a little a little on theſe defects to trace the cauſes from whence they proceed.

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* Ripened or filled with ſap.

The ſappy parts of trees is, as is well known, a crown or circle of white and imperfect wood of a greater or leſſer thickneſs, and which in almoſt all trees is eaſily diſtinguiſhed from the ſound wood, called the *heart*, by the difference of its colour and hardneſs; it is found immediately under the bark, and ſurrounds the perfect wood, which in ſound trees is nearly of the ſame colour, from the circumference to the centre. But in thoſe we now ſpeak of the perfect wood was ſeparated by another circle of white wood, inſomuch, that on cutting the trunks of them we ſaw alternatively circles of ſap and perfect wood, and afterwards a clump of the latter, which was more or leſs conſiderable, according to the different ſoils and ſituations; in ſtrong and foreſt earth it is more ſcarce than in glades and light earth.

By the mere inſpection of theſe cinctures of white wood, which we in future ſhall term *falſe ſap*, we could perceive it to be of bad quality, nevertheleſs, to be certain thereof, we had ſeveral planks ſawed two feet in length, by nine to ten inches ſquare, and having the like made from the true ſap, we had both loaded in the middle, and thoſe of the falſe ſap always broke under a leſs weight than thoſe of the true, though the ſtrength of the true ſap is very trivial in compariſon with that of formed wood.

We afterwards took ſeveral pieces of theſe two kinds of ſap, and weighed them both in the air and water, by which we diſcovered that the ſpecific weight of the natural ſap was always greater than that of the falſe. We then made a like experiment with the wood of the centre of the ſame trees, to compare it with that of the cincture which is found between theſe two ſaps, and we diſcovered that the difference was nearly the ſame as is naturally betwixt the weight of the wood of the centre of all trees and that of the circumference; thus all that is become perfect wood in theſe defective trees is found nearly in the common order. But it is not the ſame with reſpect to the falſe ſap, ſince, as theſe experiments prove, it is weaker, ſofter, and lighter than the true ſap, although formed 20, nay 25 years before, which we diſcovered to be the fact, by counting the annual circles, as well of the ſap as of the wood which covered it; and this obſervation, which we have repeated on a number of trees, inconteſtibly proves that theſe defects had been cauſed by the hard froſt of 1709, notwithſtanding the number of ſome of their coats were leſs than the years which had paſſed ſince that period; and at which we muſt not be ſurpriſed, not only becauſe we can never, by the number of lignous coats, find the age of trees within three or four years, but alſo becauſe the firſt lignous coats, formed after that froſt, were ſo thin and confined, that we cannot very exactly diſtinguiſh them.

It is alſo certain, that it was the portion of the trees that were in ſap in the hard froſt of 1709, which inſtead of coming to perfection, and converting itſelf into wood, became more faulty. Beſides, it is more natural to ſuppoſe, that the ſandy part muſt ſuffer more from ſharp froſts than ſound wood: becauſe it is not only at the external part of the tree, and therefore more expoſed to the weather, but alſo becauſe the fibres are more tender and delicate than the wood. All this at firſt appears to wear but little difficulty, nevertheleſs, the objection related in the hiſtory of the Academy of Sciences, anno 1710, might be here adduced; as by thoſe objections it appears that in 1709, the young trees much better endured the hard froſt than old. But as theſe facts are certain, there muſt be ſome difference between the organic parts, the veſſels, the fibres, &c. of the ſappy part of the old trees and that of the young; they perhaps will be more ſupple, inſomuch, that a power which will be capable of cauſing the one to break, will only dilate the other.

But as theſe are matters with which the mind remains but little ſatisfied, we ſhall paſs ſlightly over theſe conjectures, and content ourſelves with the particulars we have well obſerved. That this ſappy part ſuffered greatly from the froſt is an inconteſtible fact, but has it been entirely diſorganized? This might happen without the death of the tree enſuing, provided the bark remained ſound; and even vegetation might continue. Willows and limes frequently ſubſiſt only by their bark, and the ſame thing has been ſeen at the nurſery of Roule on an orange tree. But we do not think that the falſe ſap is dead, becauſe it always appeared to us in quite a different ſtate from the ſap found in trees, which had a portion of dead wood included in the ſound; beſides, if it had been diſorganized, as it extends over the whole circumference, it would have interrupted the lateral motion of the ſap, and the wood of the centre, not being able to vegetate, would have alſo periſhed and altered, which was not the caſe, and which I could confirm by a number of experiments; however, it is not eaſily conceived how this ſappy part of wood has been changed ſo far as not to become wood, and that far from being dead, it was even in a ſtate of ſupplying the lignous coats with ſap, which are formed from above in a ſtate of perfection, which may be compared to the wood of trees that have ſuffered no accident. This muſt nevertheleſs have been done by the hard winter which cauſed an incurable malady to this part of the tree, for if it was dead, as well as the bark which cloathed it, it is not doubtful but that the tree would have entirely periſhed, which happened in 1709 to many trees whoſe bark was detached from them, and which by the remaining ſap in their trunk, ſhot forth their buds in ſpring, but died through weakneſs before autumn, for want of receiving ſufficient nutriment to ſubſiſt on.

We have met with ſome of theſe falſe ſappy part of trees which were thicker on one ſide than the other, and which ſurpriſingly agrees with the moſt general ſtate of the ſap. We have alſo ſeen others very thin, ſo that apparently there were only the outer coats injured. Theſe were not all of the ſame colour, had not undergone an equal alteration, nor were equally affected, which agrees with what we have before advanced. At length, we dug at the foot of ſome of theſe trees, to ſee if the defect exiſted alſo in the roots, but we found them ſound: therefore, it is probable, that the earth which covered them had repaired the injury done by the froſt.

Here then we ſee one of the moſt dreadful effects of winter froſts, which though locked up within the tree, is not leſs to be feared, ſince it renders the trees attacked by them almoſt uſeleſs; but, beſides this, it is very difficult to meet with trees totally exempt from theſe injuries; and indeed all whoſe wood is not of a deeper colour at the centre, growing ſomewhat lighter towards the ſap, may be ſuſpected of having ſome defects, and ought not to be made uſe of in any matter of conſequence.

By horizontally ſawing the bottom of trees, we ſometimes perceive a piece of dead ſap or dried bark, entirely covered by the live wood: this dead ſap occupies nearly half of the circumference in the parts of the trunk where it is found: it is ſometimes browner than good wood, and at others almoſt white. By the depth alſo where this ſap is found in the trunk, it appears to have been occaſioned by the ſharp froſt in winter, by which a portion of the ſap and bark was periſhed, and afterwards covered by the new wood; for this ſap is almoſt always found expoſed to the ſouth, where the ſun melting the ice, a humidity reſults, which again freezes ſoon after the ſun diſappears, and that forms a true ice, which is well known to cauſe a conſiderable prejudice to trees. This defect does not always appear throughout the whole length of the trunk, for we have ſeen many ſquare pieces which ſeemed perfectly exempt from all defects, nor were the injuries of the froſt diſcovered until they were ſlit into planks. It is, nevertheleſs, eaſily to be conceived, how ſuch a diſorder, in their internal parts, muſt diminiſh their ſtrength, and aſſiſt their periſhing.

In foreſts, or woods, we meet with trees which ſtrong winter froſts have ſplit according to the direction of their fibres, theſe are marked with a ridge formed by the cicatrice that covers the cracks, but which remain within the trees without uniting again; becauſe a re-union is never formed in the lignous fibres when they have been divided or broken; nor can it be doubted, but that the ſap, which increaſes in volume when it freezes, as all liquors do, may produce many of theſe cracks. But we alſo ſuppoſe there are ſome which are independent of the froſt, and which have been occaſioned by a too great abundance of ſap.

Be this as it may, the fact is, we have found ſuch defects in all ſoils, and in all expoſitions, but moſt frequently in wet ground in northern and weſtern expoſitions ; the latter may perhaps proceed in caſes when the cold is more intenſe, to ſuch expoſitions ; and in the other, from the trees which are in marſhy grounds, having the tiſſue of their lignous fibres weaker, and becauſe their ſap is more abundant and aqueous than in dry land ; which may be the cauſe that the effect of the rarefaction of liquors by the pores is more perceptible, and more in a ſtate of diminiſhing the lignous fibres, as they bring leſs reſiſtance thereto.

This reaſoning ſeems to be confirmed by another obſervation; namely, that reſinous trees, as the fir, are ſeldom injured by the ſharp froſts of winter, evidently from their ſap being more reſinous ; for we know that oils do not perfectly freeze, and that inſtead of augmenting in volume, like water, in froſty weather, they diminiſh when they congeal.

Dr. Hales ſays in his *Vegetable Statics*, *p*. 16. That the plants which tranſpire the leaſt, are thoſe which beſt reſiſt the winter ; becauſe they have need only of a ſmall quantity of nutriment to preſerve themſelves. He ſays, likewiſe in the ſame part, that the plants, which preſerve their leaves during winter, are thoſe which tranſpire the leaſt; nevertheleſs, we know that the orange tree, the myrtle, and ſtill more the jeſſamine of Arabia, &c. are very ſenſible of froſt, although theſe trees preſerve their leaves during winter; we muſt, therefore, have recourſe to another cauſe to explain why certain trees which do not ſhed their leaves in winter, ſo well ſupport the ſharpeſt froſts.

We have ſawed many trees attacked with this malady, and have almoſt always found, under the prominent cicatrice, a depoſit of ſap or rotten wood, and they are eaſily diſtinguiſhed from what are called in the foreſt terms, ſinks or gutters, becauſe the defects which proceed from an alteration of the lignous fibres, which is internally produced, occaſion no cicatrice to change the external form of the trees, whereas the chinks produced by froſts, which proceed from a cleft afterwards covered by a cicatrice, make a ridge or eminence in form of a cord, which announces the internal defect.

The ſharp winter froſts produce, without doubt, many other injuries to trees, and we have remarked many defects, which we might attribute to them with great probability; but, as we have not been able to verify the fact, we

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ſhall paſs on to the effects of the advantages and diſadvantages of different expoſitions with reſpect to froſt; for this queſtion is too intereſting not to endeavour its elucidation, eſpecially as various authors have ſupported an oppoſition of ſentiment more capable of breeding doubts than increaſing our knowledge. Some have inſiſted that the froſt is felt more ſtrongly at the northern expoſition, while others aſſert it is more ſenſible to the ſouth or weſt, and all theſe opinions are founded on a ſingle obſervation. We nevertheleſs perceive what has cauſed this diverſity of opinions, and which has inclined us to reconcile them. But, before we relate the obſervations and experiments which have led us thereto, it is but juſt we ſhould give a more exact idea of the queſtion.

It is not doubted but that the greateſt cold proceeds from the north, for that is in the ſhade of the ſun, which alone, in ſharp froſts, tempers the rigour of the cold; beſides a ſituation to the north, is expoſed to the north-eaſt, and north-weſt winds, which are clearly the moſt intenſe, whether we judge by the effects which thoſe winds produce, or by the liquor of the thermometers, whoſe deciſion is much more certain. It may alſo be obſerved along the eſpaliers, that the earth is often frozen and hardened all the day towards the north, while it may be worked upon towards the ſouth. Moreover when a ſtrong froſt ſucceeds in the night, it is evident, that it muſt be much colder in the part where it is already formed, than in that where the earth is warmed by the ſun; this is alſo the reaſon why, even in hot countries, we find ſnow in the northern expoſition, on the back of lofty mountains: beſides, the liquor of the thermometer is always lower at the northern expoſition, than in that of the ſouth; therefore, it is inconteſtible, that it is colder there, and freezes ſtronger.

It is therefore certain, that all the accidents which ſolely depend on the power of the froſt, will be found more frequently at the northern expoſition than elſewhere. But yet it is not always the great power of the froſt which injures trees, for there are particular accidents, which cauſe a moderate froſt to do them more prejudice than the much ſharper, when they happen in favourable circumſtances. Of this we have already given an example in ſpeaking of that part of dead wood included in the good, which is produced by the hoar froſt, and is found moſt frequently in the expoſitions to the ſouth; and it is alſo to be obſerved, that great part of the diſorders produced in the winter of 1709, are to be attributed to a falſe thaw, which was followed by a froſt ſtill ſharper than what had preceded; but the obſervations we have made on the effects of ſpring froſts ſupply us with many ſimilar examples, which inconteſtibly prove it is not to the expoſitions where it freezes the ſtrongeſt, that the froſt commits the greateſt injuries to Vegetables. Not to dwell upon aſſertions we ſhall proceed to a detail of facts, which ſhall render theſe general poſitions clear and apparent.

In the winter 1734 we cauſed a coppice in my wood, near Montbard in Burgundy, to be cut, which meaſured one hundred and fifty-four feet, ſituate in a dry place on a flat ground, ſurrounded on all ſides with cultivated land. In this wood we left many ſmall ſquare pieces without felling them, and in a manner that each equally faced ſouth, north, eaſt and weſt. After having well cleared the part that was cut, we obſerved carefully in ſpring the growth of the young buds; the renewed tops on the 20th of April, had ſenſibly ſhot out in the parts expoſed to the ſouth, and which conſequently were ſheltered from the north by the tufted tops: theſe were the firſt buds that appeared, and were the moſt vigorous; thoſe expoſed to the eaſt appeared next; then thoſe of the weſt, and laſtly thoſe of the northern expoſition. On the 28th of April the froſt was very ſharp in the morning, accompanied by a north wind, the ſky was clear, and the air very dry, and in which manner it continued for three days. At the end of which I went to ſee in what ſtate the buds were about the clumps, and found them abſolutely blackened in all the parts expoſed to the ſouth and the ſhelter of the north wind, whereas thoſe which were expoſed to the cold north wind, which ſtill blowed, were only ſlightly injured; and with reſpect to the eaſtern and weſtern expoſitions, they were that day nearly alike injured.

The 14th, 15th, and 22d of May, it froze pretty ſharply, accompanied by the north and north-weſt winds, and I then likewiſe obſerved that all thoſe ſheltered from the wind were very much injured, but that all expoſed thereto had ſuffered but very little. This experiment appeared deciſive, and ſhewed that although it froze moſt ſtrong in parts expoſed to the north wind, yet the froſt in that ſituation did the leaſt injury to vegetables.

This circumſtance is certainly oppoſed to common prejudice: but it is not leſs the fact, and is even eaſy to be explained; for this purpoſe, it is ſufficient to pay attention to circumſtances in which froſt acts, and we ſhall diſcover that humidity is the principal cauſe of its effects, ſo that all which occaſions humidity renders, at the ſame time, the froſt dangerous to vegetables, and all that diſſipates humidity, even if it ſhould be done by increaſing the cold (for every thing that dries diminiſhes the diſaſters of a froſt) applies towards their preſervation.

We have often remarked, that in low places, where miſts and fogs reign, froſt is felt more ſharply, and oftener than elſewhere. For inſtance, in autumn and ſpring we have ſeen delicate plants frozen in a kitchen-garden, in a low ſituation, whereas the like plants were preſerved ſound in another kitchen-garden ſituated on an eminence. So, likewiſe, in vallies and low foreſts the wood is never of a beautiful vein, nor of good quality, although the vallies are often by much the beſt ſoil. The coppice wood is never good in low places, although it ſhoots forth there later than upon high places, but which is occaſioned by reaſon of a freſhneſs always concentered therein. When I walked at night in the wood I felt almoſt as much heat on eminences as in the open plains, but in the vallies I experienced a ſharp and uncomfortable cold. Though the trees ſhoot out the lateſt in thoſe parts, yet the ſhoots are ſtill injured by the froſt, which ſpoiling the principal buds obliges the trees to ſhoot forth lateral branches, and thus prevents their ever becoming ſtraight and handſome trees fit for ſervice. What we have juſt advanced muſt not only be underſtood of deep vallies, which are ſuſceptible of thoſe inconveniencies from northern expoſitions, or thoſe incloſed on the ſouthern ſide in the form of an alley, in which it often freezes the whole year, but alſo of the ſmalleſt vallies, ſo that by a little cuſtom we can diſcover the bad figure of the ſhoots from the inclination of the earth; this I particularly obſerved on the 28th of April, 1734; on that day the buds of all the trees, from one year up to ſix or ſeven, were frozen in all the lower places; whereas in the high and uncovered places there were only the ſhoots near the earth which were ſo; the earth was then very dry, and the humidity of the air did not appear to have greatly contributed to this injury. Neither vines, nor the trees of the plain, are ſubject to froſt, which might lead us to ſuppoſe they are leſs delicate than the oak; but we think this muſt be attributed to the humidity, which is always greater in the woods than in the reſt of the plains, for we have obſerved that oaks are often very much injured from froſts in foreſts, while thoſe which are in the plains are not hurt in the leaſt.

Large timbers, even on eminences, may cauſe the young trees near them to be in the ſame ſtate as if at the bottom of a valley. We have alſo remarked, that the young wood near large trees is often more injured by the froſt than in thoſe parts remote from them, as in the midſt of ſuch woods, where a great number of branches are left, it is felt with more force than in thoſe which are open. Now all theſe diſorders are moſt conſiderable in ſuch places, for as the wind and ſun cannot diſſipate the tranſpiration of the earth and plants, there remains a conſiderable humidity, which cauſes a very great prejudice to plants.

We have alſo remarked, that the froſt is never more to be dreaded, with reſpect to the vine flowers, buds of trees, &c. than when it ſucceeds miſts, or even rain, however ſlight, for they are all capable of enduring a very conſiderable degree of cold without being damaged, when it has not rained for ſome time, and the earth is dry.

Froſts likewiſe act more powerfully in places newly cultivated than in others, becauſe the vapours, which continually riſe from the earth, tranſpire more freely and abundantly from that which is newly cultivated. To this reaſon we muſt, however, ſubjoin the fact, that plants, newly ſet, ſhoot forth more vigorouſly than others, which renders them more ſenſible and liable to the effects of froſt. So alſo in light and ſandy ſoil the froſt does more injury than in ſtrong land, even though of equal dryneſs, becauſe more exhalations eſcape from the firſt kind of earths than from the latter; and if a vine newly dunged is moſt ſubject to the froſt, it ariſes from the humidity which eſcapes therefrom. A furrow of vine which lies along a field of ſainfoin, peas, &c. is often all deſtroyed by the froſt, while the reſt of the vine is quite healthy, which muſt certainly be attributed to the tranſpiration of the ſainfoin, or other plants, which bring a humidity on the ſhoots of the vine. In the vine alſo, the branches which are ſtrong and cut are always leſs injured than the ſtock; eſpecially when not attached to the props as they are then agitated by the wind which dries them.

The ſame thing is remarked of timber, and I have ſeen in copſes all the buds entirely deſtroyed by the froſt, while the upper ſhoots had not received the leaſt damage; indeed it always appeared that the froſt did moſt injury neareſt to the earth, commonly within one or two feet,

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inſomuch that it muſt be very violent to deſtroy the buds higher than four.

All theſe obſervations, which may be looked upon as very conſtant, agree to prove that it is not the ſharpeſt froſts which do the greateſt injury to plants, but that they are affected in proportion as they are loaded with humidity, which perfectly explains why the froſt cauſes ſo many diſorders to the ſouthern expoſition, although it ſhould be leſs cold than that of the north, and likewiſe why the froſt cauſes more injury to the northern expoſition, when after a rain proceeding from a weſterly wind the wind veers to the north towards ſun-ſet, as often happens in ſpring, or when, by an eaſterly wind, a cold moiſt air ariſes before ſun-riſe, which is not ſo common.

There are likewiſe circumſtances where the froſt does moſt injury to the eaſtern expoſition; but as we have many obſervations on that ſubject we ſhall firſt relate thoſe we made in the ſpring froſt in 1736, which occaſioned ſo much damage. It having been very dry the preceding winter it froze for a long time before it injured the vines; but it was not ſo in the foreſts, where there was apparently more humidity. In Burgundy it was the ſame as in the foreſt of Orleans, the underwood was injured very early. At laſt the froſt ſo greatly increaſed that all the vines were deſtroyed, notwithſtanding the dryneſs ſtill continued; but inſtead of this froſt doing much damage under the ſhelter of the wind, thoſe parts which were ſheltered were the only ones preſerved, inſomuch, that in many cloſes ſurrounded by walls the ſtocks along the ſouthern expoſition were very green, while all the reſt remained dry; and in two quarters the vines were ſaved, the one by being ſheltered from the north by a nurſery of aſh-trees, and the other becauſe the vineyard was ſtocked with a number of fruit-trees.

But this effect is very rare, and is ſuppoſed only to have happened from the ſeaſon being dry, and becauſe the vines had reſiſted the weather till the plants had became ſo ſtrong, from the time of the year, that the froſt could not injure them, independent of the external humidity, and other particular circumſtances.

But there are other cauſes to be aſſigned for the diſorders which froſt produces more frequently to the eaſt than to the weſt, and which are drawn from the following obſervations:

A ſharp froſt cauſes no prejudice to plants when it goes off before the ſun comes upon them: let it freeze at night, if the morning is cloudy, or a ſlight rain falls, or, in one word, if by any cauſe whatever the ice melts gently, and independent of the action of the ſun, it ſeldom does any injury; and we have very often ſaved very delicate plants, which had by chance remained expoſed to the froſts, by returning them into the green-houſe before ſun-riſe, or ſimply covering them before the ſun had ſhone upon them.

One time in particular a very ſharp froſt happened in autumn while our orange-trees were out of the green-houſe, and as it rained part of the night they were all covered with icicles: but this accident was prevented from doing any injury by covering them with cloths before the ſun roſe, ſo that there was only the young fruit and the moſt tender ſhoots injured, and we are perſuaded they would all have been ſaved if the covering had been thicker.

Another time our *geraniums*, and many other plants which cannot bear the froſt, were out, when ſuddenly the wind, which was ſouth-weſt, veered to the north, and became ſo cold that the rain-water, which fell abundantly, was frozen, and in almoſt a moment all that were expoſed to the air were covered with ice, upon which we had ſcarcely an idea but that all our plants were irrecoverably deſtroyed; nevertheleſs we had them carried to the furthermoſt part of the green-houſe, ſhut up the windows, and by that means they ſuſtained but little damage.

This kind of precaution is always obſerved with regard to animals; when they are ſtricken with cold, or have a limb frozen, great care is taken not to expoſe them haſtily to heat, but they are rubbed with ſnow, dipped in water, or buried in dung; in one word, the greateſt attention is paid that they ſhall gradually be brought to warmth. It is almoſt certain, with reſpect to fruit which may be frozen, that if thawed with precipitation it invariably periſhes, whereas it ſuffers but little if thawed gradually, and by degrees.

To give an explanation how the ſun produces ſo many diſorders on frozen plants, ſome have imagined that the ice, by melting, is reduced into ſmall ſpherical drops of water, which form ſo many ſmall burning mirrors when the ſun ſhines thereon. But however ſmall the form of a mirror may be, it can only produce heat at a diſtance, and can have no effect on a body it touches; beſides, the ſide of the drop of water which is on the leaf of a plant is flat, which removes its focus to a greater diſtance. In ſhort, if theſe drops of water could produce this effect why ſhould not the dew-drops, which are alſo ſpherical, produce the ſame? perhaps, it may be thought that the moſt ſpirituous and volatile parts of the ſap melting the firſt, they evaporate before the reſt are in a ſtate of moving in the veſſels of the plant, which might decompoſe the ſap.

But in general it may be ſaid, the froſt increaſing the volume of the liquor, bends the veſſels of plants, and that the thaw cannot be performed without the parts which compoſe the frozen fluid enter into motion. This change may be made with ſufficient gentleneſs not to break the moſt delicate veſſels of plants, which will by degrees return to their natural tone, and then the plants will not ſuffer any injury; but, if it is done with precipitation, theſe veſſels will not be able to retake their natural tone ſo ſoon after having ſuffered a violent extenſion, the liquors will evaporate and the plant remain dry.

Although we might conclude with theſe conjectures, with which ſome are not perfectly ſatisfied, yet we may be aſſured that it always remains conſtant.

1. That it ſeldom happens with regard to fruit, either in ſpring or winter, that the plants are injured ſimply by the force of the froſt and

independent of any particular circumſtances, and when it does it is at the northern expoſition that plants meet with the greateſt injury.

2. In froſty weather, which laſts ſeveral days, the heat of the ſun melts the ice in ſome places for a few hours; for it often freezes again before ſun-ſet, which forms an ice very prejudicial to plants, and it is obſervable that the ſouthern expoſition is more ſubject to this inconvenience than all the reſt.

3. It has been obſerved, that ſpring froſts principally diſorder thoſe places where there is humidity, the ſoils which tranſpire much, and bottoms of vallies, in general all places which cannot be dried by the wind and ſun are therefore the moſt injured.

In ſhort, if, in ſpring, the ſun which ſhines on frozen plants occaſions a more conſiderable damage to them, it is clear that it will be the eaſtern expoſition, and thoſe next the ſouth which will ſuffer moſt.

But it may be ſaid, if this is the caſe, we muſt no longer plant to the ſouthern expoſition in *a-dos* (which are ſlopes, or borders of earth, thrown up in kitchen gardens or along eſpaliers) gilliflowers, cabbages, winter lettuces, green peas, and ſuch other delicate plants as we would have ſtand the winter, and preſerve for an early crop in ſpring; and that it is to the northern expoſition alone we muſt for the future plant peach and other delicate trees. It is proper to deſtroy theſe objections, and ſhew that they are falſe conſequences of what we have advanced.

Different objects are propoſed when we ſet plants to live over the winter in ſhelters expoſed to the ſouth, and ſometimes it is to expedite vegetation: it is, for example, in this intention, that along eſpaliers we plant ranges of lettuces, which for that reaſon are termed *winter lettuces*; theſe will tolerably well reſiſt the froſt in whatever part we plant them, but are always moſt forward in this expoſition; at other times, it is to preſerve them from the rigour of this ſeaſon, with an intention of replanting them early in the ſpring. This practice is alſo followed by winter cabbages, which are ſown in this ſeaſon along an eſpalier border. Theſe kind of cabbages, like brocoli, are tender and cannot endure the froſt, and would often periſh in theſe ſhelters, if care was not taken to cover them during the ſharp froſts with ſtraw or dung ſupported on frames.

To forward the vegetation of ſome plants which will not bear the froſt, as green peas, &c. it is uſual for that purpoſe to plant them on borders expoſed to the ſouth, beſides which, they are defended from ſharp froſts when the weather requires it.

It is well known, without dwelling any longer on this point, that the ſouthern expoſition is more proper than all the reſt to accelerate vegetation, and we have ſhewn that this is alſo what is principally propoſed when ſome plants are ſet in that expoſition to live over the winter, ſince, in addition, we are alſo obliged to make uſe of coverings to guard thoſe plants which are very delicate from the froſt. But we muſt add, that if there are ſome circumſtances wherein the froſt cauſes more diſorders to the ſouthern than to other expoſitions, there are alſo many caſes which are favourable to this expoſition: for example, in winter, when there is any thing to fear from the ice, it frequently happens that the heat of the ſun, increaſed by the reflection of the wall, has ſufficient force to diſſipate all the humidity, and then the plants are almoſt perfectly ſecure againſt the cold. Beſides, dry froſts often happen, which unceaſingly act towards the north, and which are ſcarcely ever felt towards the ſouth. In ſpring, likewiſe, we perceive that after a rain which proceeds from the ſouth-weſt, or ſouth-eaſt, if the wind changes to the north, the ſouthern eſpalier being under the ſhelter of the wind, will ſuffer more than the reſt; but theſe caſes are very rare, and moſt often it is from rains, which come from the north-eaſt or north-weſt that the wind changes to the north, and then the ſouthern eſpalier having been under ſhelter from the rain by the wall, the plants there will have leſs to ſuffer than the reſt, but alſo becauſe it is always leſs cold there than in other expoſitions. It is likewiſe to be obſerved that as the ſun dries much earth along the eſpaliers which are to the ſouth, the earth tranſpires there leſs than elſewhere.

It is well known that what we have juſt advanced muſt have its application with reſpect to peach and apricot trees, which it is cuſtomary to put in this expoſition and in that of the eaſt. We ſhall only add, that it is not uncuſtomary to ſee peach trees frozen in the eaſt and ſouthern expoſitions, while thoſe are not ſo which ſtand in the weſt or north; but notwithſtanding this, we can never rely on having many, nor good peaches in this laſt expoſition, for great quantities of bloſſom fall off entirely without ſetting; others, after having ſet fall from the trees, and thoſe which remain with difficulty arrive to maturity. I have an eſpalier of peach-trees in a weſtern expoſition, a little declining to the north, which ſcarcely ever produce any fruit, although the trees are handſomer than thoſe to the ſouthern and northern. Therefore we cannot avoid the inconveniencies with reſpect of the froſt in the ſouthern expoſition without feeling others that are worſe.

All delicate trees, as fig, laurel, &c. muſt be ſet to the ſouth, and great care taken to cover them; it is only requiſite to remark that dry dung is preferable for this purpoſe to ſtraw, becauſe the latter not only does not ſo exactly cover them, but alſo from its always retaining ſome grain which attracts moles and rats, who ſometimes eats the bark of trees to quench their thirſt in froſty weather, when they can meet with no water to drink, nor herb to feed upon; and however ſingular this may appear, it is a circumſtance which has happened to us ſeveral times; but when dung is made uſe of it muſt be dry, without which it will heat and make the young branches grow mouldy.

All theſe precautions are, nevertheleſs, very inferior to the eſpaliers in niches, as in that manner plants are ſheltered from all winds, except the ſouth, which cannot hurt them; the ſun, which warms theſe places during the day, prevents the cold from being ſo violent during the night; and over theſe defended places we may put a ſlight covering with great facility, which will hold the plants there in a ſtate of dryneſs, infinitely proper to prevent all the accidents which the ſpring froſts and ice might produce; and moſt plants will not ſuffer from being deprived of their external humidity, becauſe they ſcarcely tranſpire in the winter, or in the beginning of ſpring, ſo that the humidity of the air is ſufficient for their ſupply.

But ſince the dew renders plants ſo ſuſceptible of the ſpring froſt, might we not hope, that from the reſearches of Meſſrs. Muſchenbrock and Fay, ſome plan might be drawn to prevent the bad effects thereof? for ſince there are ſome bodies which ſeem to attract dew, while others evidently repel it, if we could paint, plaſter, or waſh the walls with ſome matter which would have the latter effect, it is certain we ſhould have room to expect a more fortunate ſucceſs than from the precaution taken to place a plank in form of a roof over the eſpaliers, which cannot prevent the abundance of dew from reſting on trees, ſince Fay has proved that it very often does not fall perpendicularly like rain, but floats in the air, and attaches itſelf to thoſe bodies it encounters; ſo that frequently as much dew is amaſſed under a roof as in places entirely open. It would be eaſy for us to reviſe all our obſervations, and continue to deduce uſeful conſequences, but what we have ſaid muſt be ſufficient to ſhew the neceſſity for rooting up all trees which prevent the wind from diſſipating miſts.

Since by cultivating the earth we cauſe more exhalations to iſſue, great attention ſhould be paid not to cultivate them in critical times.

We muſt expreſsly declare againſt ſowing kitchen-plants on vine-furrows, as by their tranſpiration they hurt the vine.

Props ſhould be put to the vines as late as poſſible. The hedges, which border them on the north ſide, ſhould be kept lower than the reſt. It is preferable to improve vines with mould rather than dung. And in chooſing a ſoil we ſhould avoid thoſe which are in bottoms and grounds which tranſpire much.

A part of theſe precautions may be alſo uſefully employed for fruit-trees; with reſpect, for example, to plants which gardeners are forward to put at the feet of their buſhes and along their eſpaliers.

If there are ſome parts high and others low in a garden, we ſhould pay attention to ſow ſpring and delicate plants on elevated parts, at leaſt if we do not deſign to cover them with glaſſes, &c. but in caſes where humidity cannot hurt them it might be often advantageous to chooſe low places, where they might be ſheltered from the north and north-weſt winds.

We may alſo profit from what has been ſaid to the advantage of foreſts, for if we mean to make a reſerve of any of the trees it ſhould never be in parts where the froſt is ſevere; and in planting we ſhould pay attention to put in vallies thoſe trees which can endure the froſt better than oak.

When any conſiderable fall of timber is made we ſhould make them in roads, beginning always on the north ſide, in order that the wind, which generally blows in froſty weather, may diſſipate that humidity which is ſo prejudicial to the underwood.

There might be alſo many other uſeful conſequences drawn from our obſervations; but we ſhall content ourſelves with having recounted ſome, becauſe the ingenious man may ſupply what we have omitted by paying a little attention to the obſervations we have mentioned. We are well convinced there are a great number of further experiments to be made on this matter; and perhaps even thoſe we have related will engage ſome perſons to work on the ſame ſubject, and from our hints ſome general and uſeful advantages may be derived.

ON THE TEMPERATURE OF THE PLANETS.

THE human race can only judge of the nature and extent of the univerſe by the ſimple organ of ſight. To that the earth is a ſolid body, whoſe volume is unbounded, and whoſe extent is without limits, of which men can only ſurvey ſmall ſuperficial ſpaces. The ſun and planets ſeem to be luminous points, of which the ſun and moon appear to be the only objects worthy regard in the immenſity of the heavens. To this falſe idea on the extent of the nature and proportions of the univerſe is joined the ſtill more diſproportionate ſentiment of ſuperiority. Man, by comparing himſelf with other terreſtrial beings, feels that he ranks the firſt, and hence he preſumes that all was made for him; that the earth was created only to ſerve for his habitation, and the heavens for a ſpectacle; that in ſhort the whole univerſe ought to yield to his neceſſities, and even his pleaſures. But in proportion as he makes uſe of that divine light, which alone enobles his being,

being; in proportion as he obtains inſtruction, he is forced to abate his pretenſions ; he finds himſelf leſſened in proportion as the univerſe increaſes on his ideas, and it becomes demonſtrable to him, that the earth, which forms all his domain, and on which unfortunately he cannot ſubſiſt without trouble and ſorrow, is as ſmall with reſpect to the univerſe, as he is with reſpect to the Creator. In ſhort, from ſtudy and application, he finds there does not remain a poſſible doubt, that this earth, large and extenſive as it may ſeem to them, is but a moderate ſized planet, a ſmall maſs of matter, which, with others, has a regular courſe around the ſun : for as it appears our globe is at the diſtance of at leaſt 33 millions of leagues, and the planet Saturn at 313 millions, the natural concluſion is, that the extent of the ſun's empire is a ſphere, whoſe diameter is 627 millions of leagues, that the earth, relative to this ſpace, is not more than a grain of ſand to the volume of the globe.

However, the planet Saturn, although the fartheſt from the ſun, is not near the confines of his empire : his limits extend much farther, ſince comets paſs over ſpaces beyond that diſtance, as may be eſtimated by the period of the time of their revolutions : a comet which like that of the year 1680 circulates round the ſun in 575 years muſt be 15 times more remote from him than Saturn; for the great axis of its orbit is 138 times greater than the diſtance from the earth to the ſun. Hence we muſt ſtill augment the extent of the ſolar power 15 times the diſtance from the ſun to Saturn, ſo that all the ſpace in which the planets are included is only a ſmall province of his domain, whoſe bounds ſhould be placed at leaſt 138 times his diſtance from the earth.

What immenſity of ſpace! What quantity of matter! For independent of the planets, there is a probability of the exiſtence of 400 or 500 comets, perhaps larger than the earth, which run over the different regions of this vaſt ſphere in all directions, the terreſtrial globe only conſtituting a part thereof, a unity on 272,000, a quantity repreſented by numbers, which imagination cannot attain nor comprehend.

Neverthelefs, this enormous extent, this vaſt ſphere, is yet only a very ſmall ſpace in the immenſity of the heavens; each fixed ſtar is a ſun, a center of a ſphere equally as extenſive; and as we reckon more than 2000 of theſe fixed ſtars perceived by the naked eye, and as with teleſcopes we can diſcover ſo much the greater number as theſe inſtruments are more powerful;

the extent of the univerſe appears to be without bounds, and the ſolar ſyſtem forms only a province of the univerſal empire of the Creator; an infinite empire like himſelf.

Sirius, the moſt brilliant fixed ſtar, and which for that reaſon may be regarded as the neareſt ſun to our's, affords to our ſight only a ſecond of annual parallax on the whole diameter of the earth's orbit, and is therefore at the diſtance of 6,767,216 millions of leagues from the limits of the ſolar ſyſtem, ſuch as we have aſſigned after the depth to which comets immerſe. Suppoſing then, there is an equal ſpace from Sirius to that which belongs to our ſun, we ſhall perceive that we muſt extend the limits of our ſolar ſyſtem 742 times more than it is at preſent, as far as the aphelion of the comet, whoſe enormous diſtance from the ſun is nevertheleſs only a unit on 742 of the total diameter of the ſolar ſyſtem.

	Leagues.
Diſtance from the earth to the Sun	33,000,000
Diſtance from Saturn to the Sun	313,000,000
Diſtance from the aphelion of the Comet to the Sun	4554,000,000
Diſtance from Sirius to the Sun	677,170,000,000
Diſtance of Sirius to the point of the aphelion of the Comet, ſuppoſing that in aſcending from the ſun the comet pointed directly towards Syrius (a ſuppoſition	

which

which diminiſhes the diſtance as much as poſſible) - -	6,767,216,000,000
One half the diſtance from Sirius to the Sun, or the depth of the ſolar and ſircin ſyſtem - - -	3,385,885,000,000
Extent beyond the limits of the comet's aphelion - - -	3,381,331,000,000
Which being divided by the diſtance of the comet's aphelion, gives about -	742 ½

We can form another idea of our immenſe diſtance from Sirius, by recollecting that the ſun's diſk forms to our ſight an angle of 32 minutes, whereas that of Sirius forms only that of a ſecond; and Sirius being a ſun like ours, which we ſhall ſuppoſe of equal magnitude, ſince there is no reaſon to conceive it larger or ſmaller, it would appear to us as large as the ſun, if it was but a like diſtance. Taking therefore two numbers proportional to the ſquare of 32 minutes, and to the ſquare of a ſecond, we ſhall have 3,686,400 for the diſtance of the earth to Sirius, and one for its diſtance to the ſun; and as this unit is equal to 33 millions of leagues, we ſee how many millions of leagues Sirius is diſtant from us, ſince we muſt multiply theſe 33 millions by 3,686,400; and if we divide the ſpace between theſe two neighbouring ſuns, although at ſo great a diſtance, we ſhall ſee that the comets might be removed to a diſtance 1,800,000 times greater than that of the earth to the ſun without quitting the limits of the ſolar univerſe, and without being ſubjected to other laws than that of our ſun, and hence it may be concluded that the ſolar ſyſtem for its diameter has an extent, which, although prodigious, nevertheleſs forms only a very ſmall portion of the heavens; and we muſt infer a truth therefrom but little known, namely, that from the ſun, the earth, and all the other planets, the ſky muſt appear the ſame.

When in a ſerene and clear night we contemplate all thoſe ſtars with which the celeſtial vault is illuminated, it might be imagined that by being conveyed into another planet more remote from the ſun, we ſhould ſee theſe glittering ſtars larger, and emitting a brighter light, ſince we ſhould be ſo much nearer to them. Nevertheleſs, the calculation we have juſt made demonſtrates that if we were placed in Saturn, which is 300 millions of leagues nearer Sirius, it would appear only an 124,021ſt part bigger, an augmentation abſolutely inſenſible; from which it muſt be concluded, that the heaven, with reſpect to all the planets, has the ſame aſpect as it has to the earth. Therefore if even there ſhould exiſt comets whoſe periods of revolution might be double, or treble the period of 575 years, the longeſt known to us; if even the comets in conſequence thereof, immerſe at a depth ten times greater, there would ſtill be a ſpace 74 or 75 times deeper to reach the laſt confines, as well of the ſolar ſyſtem, as of the ſyrian; ſo that by allowing Sirius as much magnitude as our ſun has, and ſuppoſing in his ſyſtem as many or more cometary bodies than there are comets exiſting in the ſolar, Sirius will govern them as the ſun governs his, and there will remain an immenſe interval between the confines of the two empires; an interval which appears to be no more than a deſart in the vaſt ſpace, and which muſt give a ſuſpicion that cometary bodies do exiſt, whoſe periods are longer, and which are to a much greater diſtance than we can determine by our actual knowledge. Sirius may alſo be a ſun much larger and more powerful than ours; and if that is the caſe, it muſt throw the borders of his domain ſo much the farther back by approaching them to us, and at the ſame time retrench the circumference of the ſun.

I cannot avoid preſuming, that in this great number of fixed ſtars, which are all ſo many ſuns, there are ſome greater and others ſmaller than ours; others more or leſs luminous, ſome nearer, which are repreſented to us by thoſe ſtars called by aſtronomers, *ſtars of the firſt magnitude*, and many others more remote, which for that reaſon appear to us ſmaller. The ſtars called *nebulous* ſeem to want light and fire, and to be only half lighted; thoſe which appear and diſappear alternatively have, perhaps, a form flattened by the violence of the centrifugal force in their motion of rotation, and are perceivable only when they are in the full, diſappearing when they are ſideways. In this grand order of things, and in the nature of the ſtars, there are the ſame varieties, and the ſame differences, in number, ſize, ſpace, motion, form, and duration; the ſame relation, the ſame degrees, and the ſame connection, as are found in all the other orders of the creation.

Each of the ſuns being endowed like ours, and like all matter, with an attractive power, which extends to an indefinite diſtance, and decreaſes as the ſpace increaſes, analogy leads us to imagine that within each of their ſpheres there exiſts a great number of opaque bodies, planets, or comets, which circulate round them, but which being much ſmaller than the ſuns which ſerve them for heat, they are beyond the reach of our ſight.

It might be imagined that comets paſs from one ſyſtem to the other, and that being on the confines of the two empires they would be attracted by the preponderating power, and forced to obey the laws of a new maſter. But, by the immenſity of ſpace which is beyond the aphelion of our comets, it appears that the Sovereign Ruler has ſeparated each ſyſtem by immenſe deſarts, and a thouſand times larger than all the extent of known ſpaces. Theſe deſarts, which numbers cannot fathom the depth of, are external and invincible barriers, that all the powers of created nature cannot ſurmount. To form a communication from one ſyſtem to the other, and for the ſubjects of one to paſs into the other, it would be requiſite that the centre was not immoveable, for the ſun, the head of the ſyſtem, changing place, would draw with it in its courſe all the bodies which depend thereon, and hence might approach and invade another demeſne. If its rout was directed towards a weaker ſtar, it would commence by carrying off the ſubjects of its moſt diſtant provinces, afterwards thoſe more interior, and would oblige them all to increaſe its train by revolving round it; and its neighbour thus deprived of its ſubjects, no longer having planets nor comets, would loſe both its light and fire, which their motion alone can excite and ſupport ; hence this detached ſtar, being no longer maintained in its place by the equilibrium of its forces, would be obliged to change nutrition, by changing nature, and becoming an obſcure body, would, like the reſt, obey the power of the conqueror, whoſe fire would increaſe in proportion to the number of its conqueſts.

For what can be ſaid on the nature of the ſun but that it is a body of prodigious volume, an enormous maſs of matter penetrated by fire, which appears like a metal or a ſolid body in incandeſcence? And from whence can this conſtant ſtate of incandeſcence, this continually renewed production of fire proceed, whoſe conſummation does not appear to be ſupported by any aliment, and whoſe deperdition is at leaſt inſenſible, although conſtant for ſuch a great number of years? Is there, or can there be, any other cauſe of the production of this permanent fire, but the rapid motion from the ſtrong preſſure of all bodies, which revolve round this common heat, and which heats and embraces it, like a wheel rapidly turned round its axis? The preſſure, which they exercise by virtue of their weight is equivalent to the friction, and even more powerful, becauſe this preſſure is a penetrating power, which not only rubs the external ſurface but all the internal parts of the maſs: the rapidity of their motion is ſo great that the friction acquires a force almoſt infinite, and conſequently ſets the whole maſs of the axis in a ſtate of incandeſcence, light, heat, and fire, which from hence has no need of aliment to be ſupported, and which, in ſpite of the deperdition each day made by the emiſſion of light, may remain for ever without any ſenſible alteration, other ſuns rendering as much light to ours as it ſends to them, and no part of the ſmalleſt atom of fire, or any other matter, being loſt in a ſyſtem where all is attracted.

If from this ſketch of the great table of the heavens, which I have only attempted to repreſent to myſelf the proportion of the ſpaces, and that of the motion of bodies which travel over them; if from this point of view, to which I only raiſed myſelf to ſee how greatly nature muſt be multiplied in the different regions of the univerſe, we deſcend to that proportion of ſpace which we are better acquainted with, and in which the ſun exerciſes its power, we ſhall diſcover, that although it governs all bodies therein, it, nevertheleſs, has not the power of vivifying them, nor even that of ſupporting life and vegetation.

Mercury, which is the neareſt to the ſun, nevertheleſs receives only a heat 400 times ſtronger than that of the earth, and this heat, ſo far from being burning, as it has always been ſuppoſed, would not be ſtrong enough of itſelf to ſupport animated nature, for the actual heat of the ſun on the earth being only $\frac{1}{50}$ part of the heat of the terreſtrial globe, that of the ſun on Mercury conſequently is only $\frac{1}{8}$ part of the actual heat of the earth. Now if $\frac{7}{8}$ parts were ſubtracted from the heat which is at preſent the temperature of the earth, it is certain animated nature would be checked, if not entirely extinguiſhed. Since the ſun alone cannot maintain organized nature in the neareſt planet, how much more aid muſt it require to animate thoſe at a greater diſtance? To Venus it only ſends a heat $\frac{2}{50}$ times ſtronger than that it ſends to the earth, which inſtead of being ſtrong enough to ſupport animated nature, would not certainly ſuffice to maintain the liquidity of water, nor perhaps even the fluidity of air, ſince our actual temperature would be refrigerated to $\frac{2}{49}$, which is very near the term $\frac{1}{25}$ we have given as the external limit of the ſlighteſt heat, relative to living nature. And with reſpect to Mars, Jupiter, Saturn, and all their ſatellites, the quantity of heat which the ſun ſends to them, in compariſon with that which is neceſſary for the ſupport of nature, which may be looked upon as of little effect, eſpecially in the two larger planets, which, nevertheleſs, appear to be the eſſential objects of the ſolar ſyſtem.

All the planets, therefore, have always been volumes (as large as uſeleſs) of matter more than dead, profoundly frozen, and conſequently places uninhabited and uninhabitable for ever if they do not include within themſelves treaſures of heat much ſuperior to what they receive from the ſun. The heat which our globe poſſeſſes of itſelf, and which is 50 times greater than that which comes to it from the ſun, is, in fact, the treaſure of nature, the true fund which animates us as well as every being: it is this internal heat of the earth which cauſes all things to germinate and to develope; it is that which conſtitutes the element of fire, properly called an element, which alone gives motion to other elements, and which if it was reduced to $\frac{1}{20}$ could not conquer their reſiſtance, but would itſelf fall into an inertia. Now this element, this ſole active power, which may render the air fluid, the water liquid, and the earth penetrable, might it not have been given to the terreſtrial globe alone ? Does analogy permit us to doubt that the other planets do not likewiſe contain a quantity of heat, which belongs to them alone, and which muſt render them capable of receiving and ſupporting living nature ? Is it not greater and more worthy the idea we ought to have of the Creator, to ſuppoſe that there every where exiſts beings who acknowledge his power and celebrate his glory, than to depopulate all the univerſe, excepting the earth, and to deſpoil it of all beings, by reducing it to a profound ſolitude, in which we ſhould only find a deſart ſpace, and frightful maſſes of inanimate matter.

Since the heat of the ſun is ſo ſmall on the earth, and other planets, it is neceſſary they ſhould poſſeſs an heat belonging ſolely to themſelves, and our enquiry muſt be to ſee from whence this heat proceeds which alone can conſtitute in them this element of fire. Now where ſhall we be able to diſcover this great quantity of heat if it is not in the ſource itſelf, in the ſun alone ? for the matter of which the planets have been formed and projected by a like impulſion will have preſerved their motion in the ſame direction, and their heat in proportion to their magnitude and denſity. Whoever weighs theſe analogies, and conceives the power of their relations, will not doubt that the planets have iſſued from the ſun by the ſtroke of a comet, becauſe in the ſolar ſyſtem there are only comets ſufficiently powerful, and of ſufficient motion, to communicate a ſimilar impulſion to maſſes of matter which compoſe the planets. If to all theſe circumſtances we unite that of the innate heat of the earth, and of the inſufficiency of the ſun to ſupport nature, we muſt reſt perſuaded, that in the time of their formation the planets and earth were in a ſtate of liquefaction, afterwards in a ſtate of incandeſcence, and at laſt in a ſucceſſive ſtate of heat, always decreaſing from incandeſcence to actual temperance, for there is no other mode of conceiving the origin and duration of this heat proper to the earth. How to imagine that the fire, termed central, can ſubſiſt at the bottom of the globe without air (that is, without its firſt aliment, and from whence this fire ſhould proceed, which is ſuppoſed to be ſhut up in the centre of the globe) is difficult, becauſe what origin, what ſource, ſhall we then find for it? Deſcartes has imagined the earth and planets were only ſmall incruſted ſuns, in other words, ſuns entirely extinguiſhed. Leibnitz has not heſitated to pronounce that the terreſtrial globe owes its ſource, and the conſiſtence of its matters, to the element of fire; yet theſe two great philoſophers had not the aſſiſtance of theſe numerous circumſtances and obſervations which have been acquired and collected in our days, and which are ſo well eſtabliſhed that it appears more than probable that the earth, as well as the planets, were projected out of the ſun, and conſequently of a like matter, which being at firſt in a ſtate of liquefaction obeyed the centrifugal power, at the ſame time as it collected itſelf together by that of attraction, which has given a round form to all the planets under the equator, and flattened under the poles, by reaſon of the variety of their rotation; that afterwards this fire being gradually diſſipated, the benign temperature, ſuitable to organized nature, ſucceeded in different planets according to the difference of their thickneſs or denſity. If there ſhould be other particular cauſes of heat aſſigned for the earth and planets, which might combine with thoſe whoſe effects we have calculated, our reſults are not leſs curious, nor leſs uſeful to the advancement of ſcience; and we ſhall here only obſerve, that thoſe particular cauſes may prolong the time of the refrigeration of the globe, and the duration of living nature, beyond the terms we have indicated.

But I may be aſked is this Theory equally as well founded in every point which ſerves for its baſe; is it certain, according to your experiments, that a globe, as large as the earth, and compoſed of the ſame matters, cannot refrigerate from incandeſcence to actual temperature in leſs than 74,000 years, and that in order to become heated to the point of incandeſcence a 15th of this time would be required; and alſo that it ſhould be ſurrounded all that time by the moſt violent fire; hence you may ſay there are ſtrong preſumptions that this great heat of the earth could not have been communicated to it from a diſtance, and that conſequently the terreſtrial matter formerly made a part of the maſs of the ſun; but it does not appear equally proved that the heat of this body on the earth is at preſent but $\frac{1}{50}$ part of the heat of the globe. The teſtimony of our ſenſes ſeems to refute this opinion, which you lay down as a certain truth, for although we cannot doubt that the earth has an innate heat, which is demonſtrated by its always equal temperature, in all deep places where the coldneſs of the air cannot communicate; yet does it reſult that this heat, which appears of a moderate temperature, is greater than that of the ſun which ſeems to burn us ?

To all theſe objections I can give full ſatisfaction, but muſt previouſly reflect on the nature of our ſenſations. A very ſlight, and often imperceptible, difference in the cauſes which affect us, produces conſiderable ones in their effects. Is there any thing which comes nearer to extreme pleaſure than grief ? and who can aſſign the diſtance between the lively ſenſation by which we are moved with delight, and the friction which gives us pain ? between the fire which warms and that which burns ? between the light which is agreeable to our ſight and that which blinds us ? between the ſavour which pleaſes our taſte and that which is diſagreeable ? between the ſmell which will be agreeably affected at firſt by a ſmall quantity and yet ſoon after become nauſeated ? We muſt therefore ceaſe from being aſtoniſhed that a ſmall augmentation of heat, ſuch as $\frac{1}{50}$ ſhould appear ſo ſtriking.

I do not pretend poſitively to aſſert that the innate heat of the earth is really 49 times greater than that which comes to it from the ſun : for as the heat of the globe belongs to all terreſtrial matter, we have no portion by which we can ſeparate it, nor conſequently any ſenſible and real limits to which we might relate it. But even if the ſolar heat is greater or ſmaller than we have ſuppoſed, relative to the terreſtrial heat, our theory would only alter the proportion of the reſults.

For example, if we include the whole extent of our ſenſations of the greateſt heat to the greateſt cold, within the limits given by the obſervations of M. Amontons, that is, between ſeven and eight, and at the ſame time ſuppoſe that the heat of the ſun can alone produce this difference of our ſenſations, we ſhall from thence have the proportion of 8 to 1 of the innate heat of the terreſtrial globe to that which proceeds from the ſun; and conſequently the compenſation which this heat of the ſun actually makes on the earth, would be $\frac{1}{8}$ and the compenſation which it made in the time of incandeſcence will have been $\frac{1}{260}$: adding together theſe two terms, we have $\frac{26}{900}$ which multiplied by $12\frac{1}{2}$, the half of the ſum of all the terms of the diminution of heat, gives $\frac{325}{400}$ or $\frac{5}{8}$ for the total compenſation made by the ſun's heat during the period of 74047 years of the refrigeration of the earth to actual temperature. And as the total loſs of the innate heat is to the total compenſation in the ſame ratio as the time of the period of refrigeration, we ſhall have 25 : 1 $\frac{5}{8}$: : 74047 : 4813 $\frac{1}{25}$, ſo that the refrigeration of the globe of the earth inſtead of having been prolonged only 770 years, would have been 4813 $\frac{1}{25}$ years; which joined to the longeſt prolongation, the heat of the moon would alſo produce in this ſuppoſition, would give more than 5000 years.

If we adopt the limits laid down by M. de Marian, which are from 31 to 32, and ſuppoſe that the ſolar heat is no more than $\frac{1}{32}$ of that of the earth, we ſhall have only $\frac{1}{4}$ of this prolongation, about 1250 years, inſtead of 770 which gives the ſuppoſition of $\frac{1}{50}$ which we have adopted.

But if we ſuppoſe that the ſun's heat is only $\frac{1}{250}$ of that of the earth, as appears to reſult from the obſervations made at Paris, we ſhould have for the compenſation of the incandeſcence $\frac{1}{6250}$ and $\frac{1}{250}$ for the compenſation to the end of the period of 74047 years of the refrigeration of the terreſtrial globe to actual temperature, and we ſhould find $\frac{17}{250}$ for the total compenſation made by the heat of the ſun during this period, which would give only 154 years, or the 5th part of 770 years for the time of the prolongation of refrigeration. And likewiſe, if in the place of $\frac{1}{50}$ we ſuppoſe that the ſolar heat was $\frac{1}{50}$ of the terreſtrial, we ſhould find that the time of prolongation would be five times longer, that is, 3850 years; ſo that the more we endeavour to increaſe the heat which comes to us from the ſun relative to that which emanates from the earth, the more we ſhall extend the duration of nature, and date the antiquity of the world farther back; for by ſuppoſing the heat of the ſun was equal to the innate heat of the globe, we ſhould find that the time of prolongation would be 38504 years, which conſequently gives the earth a greater antiquity of 38 or 39000 years.

If we caſt our eyes on the table which M. de Mairan has calculated with great exactneſs, and in which he gives the proportion of the heat which comes to us from the ſun, to that which emanates from the earth in all climates, we ſhall diſcover a well atteſted fact, which is, that in all climates where obſervations have been made, the ſummers are equal, whereas the winters are prodigiouſly unequal; this learned phyſician, attributes this conſtant equality of the intenſity of heat in ſummer in all climates to the reciprocal compenſation of the ſolar heat, and from the heat of the emanations of the central fire.

All phyſicians who have employed themſelves on this point agree with me that the terreſtrial globe poſſeſſes of itſelf a heat independent of that which comes from the ſun. Is it not evident that this innate heat ſhould be equal at every place on the ſurface of the globe, and that there is no other difference in this reſpect than that which reſults from the ſwelling of the earth at the equator, and of its flatneſs under the poles? A difference, which being in the ſame ratio nearly as the two diameters, does not exceed $\frac{1}{230}$, ſo that the innate heat of the terreſtrial ſpheriod muſt be $\frac{1}{230}$ times greater under the equator than under the poles. The deperdition which is made, and the time of refrigeration muſt, therefore, have been quicker, or more ſudden, in the northern climates, where the thickneſs of the globe is not ſo great as in the ſouthern climates, but this difference of $\frac{1}{230}$ cannot produce that of the inequality of the central emanations, whoſe relation to the heat of the ſun in winter being equal 50 to 1 in the adjacent climates to the equator, is found double to the 27th degree, triple to the 35th, quadruple to the 40th, tenfold to the 49th, and 35 times greater to the 60th degree of latitude. This cauſe, which preſents itſelf, contributes to the cold of the northern climates, but it is inſufficient for the effect of the inequality of the winters, ſince this effect would be 35 times greater than its cauſe to the 60th degree, and even exceſſive in climates nearer the poles; at the ſame time it would in no part be proportional to this ſame cauſe.

On the other hand there is not any foundation for ſupporting an attempt to maintain that in a globe which has received, or which poſſeſſes a certain degree of heat, there might be ſome parts therein much colder than others. We are ſufficiently acquainted with the progreſs of heat, and the phenomena of its communication, to be convinced that it is every where diſtributed alike, ſince by placing a cold body on one that is hot the latter will communicate to the other ſufficient heat to render both of the ſame degree of temperature in a ſhort time. It muſt not, therefore, be ſuppoſed that towards the poles there are ſtrata of colder matters leſs permeable to the heat than in other climates, for, of whatſoever nature they may be ſuppoſed, experience has demonſtrated that in a very ſhort time they would become as hot as the reſt.

The great cold in the north plainly does not proceed from theſe pretended obſtacles which might oppoſe themſelves to the iſſue of heat, nor from the ſlight difference which that of the diameters of the terreſtrial ſpheriod muſt produce; but it appears to me, after repeated reflections thereon, that we ought to attribute the equality of the ſummers, and the great inequality of the winters to a much more ſimple cauſe.

It is certain that the ſummers ſhould every where be nearly alike, becauſe the heat of the ſun forms only a ſmall augmentation to the real fund of the innate heat of the earth, that emitted from the ſun being no more than $\frac{1}{50}$ part of the heat of the globe; the longer or ſhorter ſtay of it on the horizon, its greater or leſs obliquity on the climate, and even its total abſence, would only produce one-fiftieth difference on the temperature of the climate, and hence the ſummers muſt appear, and are, in fact, nearly equal in all the climates of the earth. But what makes the winters ſo very unequal is the emanations of this internal heat of the globe being in a great meaſure ſuppreſſed as ſoon as the cold and froſt bind and conſolidate the ſurface of the earth and waters.

This heat, which iſſues from the globe, decreaſes in the air in proportion, and in the ſame ratio as the ſpace increaſes, and the ſole condenſation of the air by this cauſe is ſufficient to produce cold winds, which acting againſt the ſurface of the earth, binds and freezes it. As long as this confinement of the external ſtrata of the earth remains, the emanations of the internal heat are retained, and the cold appears to be, nay in fact is, very conſiderably increaſed by this ſuppreſſion of a part of this heat, but as ſoon as the air becomes milder, and the ſuperficial ſtrata of the globe loſes its rigidity, the heat, retained all the time of the froſt, iſſues out in greater abundance than in climates where it does not freeze, ſo that the ſum of the emanations of the heat becomes equal and every where alike; and this is the reaſon that plants vegetate quicker, and the harveſt is reaped in much leſs time in northern countries; and for the ſame reaſon it is, that often at the beginning of ſummer we feel ſuch conſiderable heats.

If there was any doubt of the ſuppreſſion of the emanations of the internal heat by the effect of froſt, we might eaſily be convinced of the fact; for it is a circumſtance univerſally known, that after a froſt, we may perceive ſnow to thaw in pits, aqueducts, ciſterns, quarries, ſubterraneous vaults or mines, when even theſe depths, pits or ciſterns, contain no water; the emanations of the earth having their free iſſue through theſe kinds of vents, the ground which covers this top is never frozen ſo ſtrong as the open land; to the emanations it permits their general courſe, and their heat is ſufficient to melt the ſnow, eſpecially in hollow places, at the ſame time that it remains on all the reſt of the ſurface where the earth is not excavated.

This ſuppreſſion of the emanations of the innate heat of the earth is not only made by the froſt, but likewiſe by the ſimple binding of the earth, often occaſioned by a leſs degree of cold than that which is neceſſary to freeze the ſurface; there are very few countries where it freezes in the plains beyond the 35th degree latitude, particularly in the northern hemiſphere. It appears, therefore, that from the equator, as far as the 35th degree, the emanations of the terreſtrial heat having always their free iſſue, there ought to be in that part little or no difference between winter and ſummer, ſince this difference proceeds only from two cauſes, both too ſlight to produce any ſenſible effect. The firſt cauſe is the difference of the ſolar action, but as this action is itſelf much ſmaller than that of the terreſtrial heat, its difference is too inconſiderable to be regarded as any thing. The ſecond cauſe is the thickneſs of the globe, which towards the 35th degree, is near $\frac{1}{590}$th part leſs than at the equator, but even this difference can only produce a very ſlight effect, ſince at 35 degrees the relation of the emanations of the terreſtrial to the ſolar heat is in ſummer from 33 to 1, and in winter from 153 to 1, which gives 186 to 2 or 93 to 1. From hence it can be only owing to the conſolidation of the earth occaſioned by the cold, or even to the cold produced by the durable rains which fall in theſe climates, that we can attribute this difference between winter and ſummer; the binding of the earth by cold ſuppreſſes a part of the emanations of the internal heat, and the cold, always renewed by the fall of rain, diminiſhes its intenſity; theſe two cauſes, therefore, together produce the difference between winter and ſummer.

After having proved that the heat which comes to us from the ſun is greatly inferior to the innate heat of our globe; after having explained that, by ſuppoſing it only $\frac{1}{50}$ part, the refrigeration of the globe to actual temperature cannot be made but in 75,832 years; after having demonſtrated that the time of this refrigeration would ſtill be longer, if the heat ſent from the ſun to the earth was in a greater relation, namely, of $\frac{1}{25}$ or $\frac{1}{10}$ inſtead of $\frac{1}{50}$, we cannot be blamed for having adopted the proportion which appears the moſt plauſible by phyſical reaſonings, and at the ſame time the moſt probable, by not extending too far back the time of the commencement of nature, which we have fixed at 37 or 38,000 years, dating it from the firſt day.

I nevertheleſs acknowledge that this time, all conſiderable as it is, does not appear ſufficiently long for certain changes, certain ſucceſſive alterations, which Natural Hiſtory demonſtrates to have taken place, and which ſeems to have required a ſtill longer courſe of centuries; and from which I ſhould be inclined to imagine, that, in reality, this time would be increaſed perhaps double if every phenomena was completely inveſtigated; but I have confined myſelf to the leaſt terms, and reſtrained the limits of time as much as poſſible, without contradicting facts and experiments.

This theory, perhaps, may be attacked by another objection, which is right to guard againſt. It may be told me that I have ſuppoſed, after Newton, the heat of boiling water three times greater than that of the ſun in ſummer, and iron heated red hot eight times greater than boiling water, that is, 24 or 25 times greater than that of the actual temperature of the earth, and that there is ſomething hypothetical in this ſuppoſition, on which I have founded the ſecond baſis of my calculations, whoſe reſults would be, without doubt, very different if this red heat of iron, or glaſs, in incandeſcence, inſtead of being, in fact, 25 times greater than the actual heat of the globe, was, for example, only 5 or 6 times as great.

The better to know the force of this objection, let us make a calculation of the refrigeration of the earth, in the ſuppoſition that in the time of incandeſcence it was only five times hotter than it is according to our calculations, this ſolar heat, inſtead of a compenſation of $\frac{1}{50}$ would have only made the compenſation of $\frac{1}{250}$ in the time of incandeſcence, theſe two terms added together gives $\frac{6}{250}$, which multiplied by $2\frac{1}{2}$, the half of the ſum of all the terms of the diminution of heat, gives $\frac{15}{250}$ for the total compenſation which the heat of the ſun has made during the whole period of the deperdition of the innate heat of the globe, which is 74047 years: therefore we ſhall have : $\frac{15}{250}$: : 74047 : 888 $\frac{14}{25}$, from which we ſee that the prolongation of refrigeration, which for a heat 28 times greater than actual temperature, has been only 770 years, ſhould have been 888 $\frac{14}{25}$, in the ſuppoſition that this firſt heat ſhould have been only five times greater than this actual temperature. This alone ſhews us that if we even ſuppoſe this primitive heat below 25, there would be only a longer prolongation of the refrigeration of the globe, and that alone appears to me ſufficient to ſatisfy the objection.

It may likewiſe be ſaid, "you have calculated the duration of the refrigeration of the planets, not only by the inverted ratio of their diameter, but alſo by the inverted ratio of their denſity; this might be well founded if we could imagine that in fact there exiſts matter whoſe denſity is as different from that of our globe: but does it exiſt? What, for example, will be the matter of which Saturn is compoſed, ſince its denſity is more than five times leſs than that of the earth?"

To this I anſwer, that it would be very eaſy to find, in the vegetable claſs, matters five or ſix times leſs denſe than a maſs of iron, marble, hard calcareous ſtone, &c. but without quitting the mineral kingdom, and conſidering the denſity of theſe five matters, we have 21 $\frac{10}{72}$ for iron, 8 $\frac{25}{72}$ for white marble, for gres 7 $\frac{24}{72}$, for common marble and calcareous ſtone 7 $\frac{20}{72}$; taking the mean term of the denſities of theſe five matters, of which the terreſtrial globe is principally compoſed, we find its denſity to be 10 $\frac{5}{18}$. It is therefore required to find a matter whoſe denſity is in the relation of 189 to 1000 denſity, which is the ſame as that between Saturn and the Earth. Now this matter might be a kind of pumice-ſtone, ſomewhat leſs denſe than common pumice ſtone, whoſe relative denſity is here 1 $\frac{66}{70}$; from whence it appears that Saturn is principally compoſed of a light matter ſimilar to pumice ſtone.

So likewiſe the denſity of the Earth being to that of Jupiter as 1000 to 292, we muſt ſuppoſe that Jupiter is compoſed of a more denſe matter than pumice ſtone, but much leſs denſe than chalk.

The denſity of the Earth being to that of the Moon as 1000 to 702, this ſecondary planet appears compoſed of a matter whoſe denſity is not quite ſo great as that of hard calcareous ſtone, but more ſo than ſoft.

The denſity of the Earth being to that of Mars as 1000 to 730, this planet muſt be compoſed of a matter ſomewhat more denſe than that of gres, and not ſo great as that of white marble.

But the denſity of the Earth being to that of Venus as 1000 to 12700, it may be ſuppoſed that this planet is chiefly compoſed of a more denſe matter than emery, and leſs denſe than zinc.

In fine, the denſity of the Earth being to that of Mercury : : 1000 : 2040, or : : 10 $\frac{5}{18}$: 20 $\frac{666}{1000}$, it muſt be thought that this planet is compoſed of matter leſs denſe than iron, but more ſo than tin.

To the queſtion, how can animated nature, which you ſuppoſe every where eſtabliſhed, exiſt in planets of iron, emery, or pumice ſtone? I ſhall anſwer, by the ſame cauſes, and by the ſame means as it exiſts on the terreſtrial globe, although compoſed of ſtone, gres, marble, iron, and glaſs. There are other planets like our globe, whoſe principal is one of theſe matters; but the external cauſes will ſoon have altered its ſuperficial ſtrata, and according to the different degrees of heat or cold, dryneſs or humidity, they will have converted this matter into a fertile earth proper to receive the ſeeds of organized nature, which only needs heat and moiſture to develope itſelf.

Having ſatisfied the objections which appeared firſt to preſent themſelves, it is neceſſary to explain the facts, and obſervations, by which we are aſſured the ſun is only an acceſſory to the real heat, which continually emanates from the globe of the earth; and it will be juſt, at the ſame time, to ſee how comparable thermometers have taught us in a certain manner that the heat in ſummer is equal in all the climates of the earth, excepting Senegal, and ſome other parts of Africa, where the heat is greater than elſewhere.

It may be demonſtrated by inconteſtible valuations, that light, and conſequently the heat of the ſun, emitted on the earth in the ſummer, is very great, comparatively with that emitted by the ſame body in winter; and yet, by very exact and reiterated obſervations, the difference of the real heat of the ſun in ſummer is very ſmall. This alone would be ſufficient to prove that the heat of the ſun makes only a ſmall part of that of the terreſtrial globe; but in addition to which M. Amontons, by receiving the rays of the ſun on the ſame thermometer in ſummer and winter, obſerved, that the greateſt heat in ſummer in our climate differs from the cold in winter, when the water congeals, as only 7 differs from 6; whereas it can be demonſtrated that the action of the ſun in ſummer is about 66 times greater than that of the ſun in winter; it therefore cannot be doubted, that there is a fund of very great heat in the terreſtrial globe, on which, as a baſe, the degrees of heat ariſe, and that at the ſurface it does not give a greater quantity of heat than that which comes from the ſun.

If it be aſked, how we can then aſſert that the heat in ſummer is 66 times greater than that in winter in our climate? I cannot give a better anſwer than by referring to the memoirs given by the late M. de Mairan in 1719, 1722, and 1765, and inſerted in thoſe of the Academy, becauſe in thoſe periods he examined, with a ſcrupulous attention, the viciſſitudes of ſummers in different climates; the various cauſes for which may reduced to four principal ones: 1. The inclination under which the light of the ſun falls according to the different height of the ſun on the horizon; 2dly. The greater or leſs intenſity of light in proportion as its paſſage in the atmoſphere is more or leſs oblique; 3dly. The different diſtance of the earth to the ſun in ſummer and winter; and 4thly. The inequalities of the length of days in different climates. By the principal that heat is proportional to the action of light it will be eaſily demonſtrated, that theſe four united cauſes, combined and compared, diminiſhes, with reſpect to our climate, this action of the ſun's heat in a ratio of about 66 to 1 between the ſummer and the winter ſolſtice; and this theory may be regarded as certain, as the ſecond truth from experience, and which demonſtrates, by the obſervations of the thermometer, immediately expoſed to the ſun's rays in winter and ſummer, that the difference of real heat in theſe two is, nevertheleſs, at moſt only from 7 to 6; I ſay at moſt, for this determination given by M. Amontons is not near ſo exact as that which has been made by M. de Mairan, who, after a great number of ulterior obſervations, proves that this relation is only as 32 to 31. What, therefore, muſt indicate this prodigious inequality between theſe two relations of the action of the *ſolar heat*, which is from 66 to 1; and of that of the *real heat*, which is only from 32 to 31 between ſummer and winter? Is it not evident that the innate heat of the globe of the earth is conſiderably greater than that which comes to us from the ſun? It appears, in fact, that in the climate of Paris this heat of the earth is 29 times greater in ſummer, and 491 times greater in winter than that of the ſun, as M. de Mairan has determined it. But I have already ſaid that we muſt not conclude, from theſe two combined relations, the real relation of the heat of the globe of the earth to that which comes from the ſun, and I have given reaſons which have determined me to ſuppoſe that we may eſtimate this heat of the ſun 49 times leſs than the heat which emanates from the earth.

From the year 1701 to 1756 incluſive, we made a variety of obſervations with thermometers, and the following were the reſults: we collected the greateſt degree of heat, and that of cold, which was experienced at Paris in each year; we made a total of theſe, and found that the mean eſtimate, in all the thermometers, reduced to Rheaumur's diviſion, was 1026, for the greateſt heat in ſummer, that is 26 degrees above the freezing point; and that the mean degree of cold in winter, during thoſe 56 years, was 994, or 6 degrees below the freezing point of water, from whence we concluded that the greateſt heat in our ſummers at Paris differs from the greateſt cold of our winters only $\frac{1}{32}$, ſince 994 : 1026 : : 31 : 32; and it was on this foundation that we ſtated the latter to be the relation of the greateſt heat to the greateſt cold. But it may be objected againſt the preciſion of this valuation, the defect of the conſtruction of the thermometer, and Rheaumur's diviſion (to which we have here reduced the ſcale of all the reſt); and this defect is extending only 1000 degrees below that of ice, as if 1000 degrees was, in fact, that of abſolute cold, whereas abſolute cold does not exiſt in nature; and that of the ſmalleſt heat ſhould be ſuppoſed 10,000 inſtead of 1,000, which would alter the thermometer's gradation. It may likewiſe be ſaid that it is not impoſſible that all our ſenſations between the greateſt heat and the greateſt cold are compriſed in as ſmall an interval as that of an unit on 32 of heat, but that the voice of judgment ſeems to be raiſed againſt this opinion, and tells us this limit is too confined, and that it is much eaſier to reduce this interval than to give it an eighth or a ſeventh inſtead of a thirty-ſecond.

But be this valuation as it may, there can be no doubt of the truth of theſe facts, which we have drawn from our obſervations, for in the ſame manner as we found, from the attention of 56 ſucceſſive years, the heat of ſummer at Paris 1026, or 26 degrees above the freezing point, we alſo found, with the ſame thermometers, that the heat in ſummer was 1026 in every climate of the earth, from the equator to the polar circle; at Madagaſcar, in the iſlands of France and Bourbon, Roderigo, Siam, and the Eaſt-Indies; at Algiers, Malta, Cadiz, Montpelier, Lyons, Amſterdam, Upſal, Peterſburgh, and as far as Lapland, near the polar circle. At Cayenne, Peru, Martinico, Carthagena in America; at Panama; in ſhort, in all the climates of the two hemiſpheres and continents where obſervations could be made, it has been conſtantly found that the liquor of the thermometer roſe equally to 25, 26, or 27 degrees in the hotteſt days in ſummer; and from hence enſues the inconteſtible fact of the equality of heat in ſummer in all climates of the earth. There are indeed ſome exceptions, for at Senegal, and ſome few other places, the thermometer riſes 5 or 6 degrees higher, to 31 or 32 degrees; but that ariſes from accidental and local cauſes, which do not alter the truth of the obſervations, nor the certainty of this general fact, which alone might likewiſe demonſtrate to us, that there really exiſts a very great heat in the terreſtrial globe, that the effect, or the emanations, of which are nearly equal in all the points of its ſurface, and that the ſun, very far from being the only ſphere of heat which animates nature, is at beſt only the regulator. This important fact, which we conſign to poſterity, will diſcover the real proportion of the diminution of the heat of the terreſtrial globe, which we have been only able to determine in a hypothetical manner. In a few centuries, I am confident, it will be found that the greateſt heat of ſummer, inſtead of raiſing the liquor of the thermometer to 26, will not raiſe it more than to 25, or 24; and from this effect, which is the reſult of all the combined cauſes, a judgment may be formed of the value of each of the particular cauſes, which the total effect of heat produces to the ſurface of the globe; for the heat which belongs to the earth, and which it has poſſeſſed from the time of incandeſcence, has very conſiderably diminiſhed, and will continue to diminiſh with the courſe of time; this heat is independent of that which comes from the ſun; the latter may be looked upon as conſtant, and conſequently in futurity will make a greater compenſation than at preſent. To the loſs of this innate heat of the globe there are two other particular cauſes, which may add a conſiderable quantity of heat to the effect of the two firſt, the only ones we have as yet taken notice of.

One of theſe particular cauſes proceeds, in ſome meaſure, from the firſt general cauſe, and may add ſomething thereto. It is certain that during the time of incandeſcence, and in all the ſubſequent ages till that of the refrigeration of the earth, not any of the volatile matters could reſide at the ſurface, or even in the internal part, of the globe; they were raiſed and diſperſed in the form of vapours, and could not depoſit themſelves but ſucceſſively in proportion as it cooled, by which means ſome of theſe matters have penetrated through the clefts and crevices of the earth to great depths, in an infinity of places; and this is the primitive foundation of volcanos, which are all found in lofty mountains, where the clefts of the earth are ſo much the greater as theſe points of the globe are more projecting and iſolated. This depoſit of the volatile combuſtible matters of the firſt ages will have been greatly augmented by the addition of every combuſtible matter which has been ſubſequently formed. Pyrites, ſulphurs, coal, bitumen, &c. have penetrated into the principal cavities of the earth, and produced almoſt every where great maſſes of inflammable matters, and often conflagrations, which have been manifeſted by earthquakes, eruptions of volcanos, and by the hot ſprings which flow from mountains, or run internally in the cavities of the earth. It may, therefore, be preſumed that theſe ſubterraneous fires, ſome of which burn without exploſion, and others with great noiſe and violence, ſomewhat increaſe the general heat of the globe. Neverheleſs this addition of heat can be only very ſlight, for it has been obſerved that it is nearly as cold on the top of volcanos as on the top of other mountains of the ſame height, excepting at the time when the volcano throws out inflamed vapours or burning matters.

The ſecond cauſe, which ſeems not to have been thought of, is the motion of the moon round the earth. This ſecondary planet performs its evolution round the earth in 27 days and one third, and being 85,325 leagues diſtant, it goes over a circumference of 436,329 leagues in this ſpace of time, which makes a motion of 817 leagues in an hour, or from 13 to 14 leagues a minute. Although this rout is, perhaps, the ſloweſt of all the celeſtial bodies, yet it is rapid enough to produce on the earth, which ſerves for the axis or pivot to this motion, a conſiderable heat by the friction which reſults from the weight and velocity of this planet. But it is not poſſible to value the quantity of heat produced by this exterior cauſe, becauſe hitherto we have had nothing which might ſerve us for a term of compariſon. But if we ever can diſcover the number, magnitude, and velocity, of all the planets which circulate round the ſun, we ſhall then be able to judge of the quantity of heat which the moon can give to the earth, by the much greater quantity of fire which all theſe vaſt bodies excite in the ſun. For my own part I am greatly inclined to think that the heat produced by this cauſe in the globe of the earth, does not prevent it from making alſo a very conſiderable part of its own heat: and that, in conſequence, we muſt ſtill extend the limits of time for the duration of nature. But let us return to our principal object.

We have obſerved that the ſummers are very nearly equal in all the climates of the earth, and that this truth is founded on inconteſtible facts; but it is not the ſame with reſpect to winters, they are very unequal, and vary in different climates, as we remove farther from that of the equator, where the heat in winter and ſummer is nearly the ſame. I think I have already explained in a ſatisfactory manner, the cauſe of the inequality by the ſuppreſſion of the terreſtrial heat. This ſuppreſſion is, as I have ſaid, occaſioned by the cold winds which fall from the air, bind the earth, freeze the waters, and ſhut up the emanations of the terreſtrial heat during the time the froſts remain; ſo that it is not at all ſurpriſing that the cold in winter is in fact ſo much the greater as we advance further towards the climates where the maſs of air, receiving the rays of the ſun more obliquely, is for that reaſon colder.

But, with reſpect to the cold as well as to the heat, there are ſome countries which are an exception to the general rule. At Senegal, Guinea, Angola, and probably in every country where the natives are black, as in Nubia, the country of the Papous, New Guinea, &c. it is certain that the heat is greater there than in any other part of the earth; but it is from thoſe local cauſes which we have explained, and therefore in thoſe particular climates where the eaſt wind reigns during the whole year, paſſes over a very conſiderable track of land, and receives a ſcorching heat before it arrives to them, it is not ſurpriſing that the heat is found 5, 6, and even 7 degrees greater than it is elſewhere. The exceſſive colds of Siberia, are alſo to be attributed to that part of the ſurface of the globe being much higher than that which ſurrounds it. "The northern Aſiatic countries (ſays the Baron Strahlenberg in his Deſcription of the Ruſſian Empire) are conſiderably more elevated than the European. They are like a table, in compariſon of the bed on which they appear to be placed; for on coming from the weſt and leaving Ruſſia, we paſs to the eaſt by the mountains Ripha and Rymnikas to enter Siberia, and conſtantly advance on an aſcent." "There are many places in Siberia, ſays M. Gmelin, which are not leſs elevated above the reſt of the earth, nor leſs remote from its centre, than are many high mountains in many other regions." Theſe plains of Siberia appear, in fact, to be as high as the ſummit of the Riphean mountains, on which the ice and ſnow do not wholly melt during ſummer; and if the ſame effect does not happen in the plains of Siberia, it is becauſe they are leſs detached, for this local circumſtance alſo adds much to the duration and to the intenſity of cold and heat. A vaſt plain once made hot will retain its heat longer than a detached mountain, although both are alike elevated; and for the ſame reaſon the mountain once cooled will retain its ſnow or ice longer than the plain.

But if we compare the exceſs of heat with that of cold produced by theſe particular and local cauſes, we ſhall be ſurpriſed to find, that in Senegal, &c. where the heat is greateſt, it never exceeds ſeven degrees beyond the ſummer heat in other countries, which is 26 degrees above the freezing point, whereas the colds of Siberia ſometimes reach 60 or 70 degrees below it, and that at Peterſburgh, Upſal, &c.

under the ſame latitude as Siberia, the greateſt cold is not more than to 25 or 26 degrees below the freezing point; therefore, we muſt conclude, that theſe local cauſes have much more influence in cold than in hot climates. Altho' we cannot pretend to determine what this great difference in the exceſs of cold and heat may produce, yet by reflecting thereon, it appears that we may eaſily conceive the reaſon of this difference. The augmentation of the heat in ſuch a climate as Senegal can only proceed from the action of the air, the nature of the ſoil, and the depreſſion of the ground; this country being almoſt on a level with the ſea, is in a great meaſure covered with ſcorching ſands, and over which an eaſterly wind continually blows, which, inſtead of refreſhing the air, only renders it more burning, becauſe it traverſes over more than 2000 leagues of land in its way, and conſequently acquires a conſiderable degree of heat. But in ſuch countries as Siberia, where the plains are elevated like the ſummits of mountains above the level of the reſt of the earth, this ſole difference of elevation muſt produce an effect proportionally more than the depreſſion of the ground of Senegal, which cannot be ſuppoſed greater than that of the level of the ſea; for if the plains of Siberia are only elevated 4 or 500 fathoms above the level of Upſal, or Peterſburgh, we muſt ceaſe from being aſtoniſhed that the exceſs of cold is ſo great there; ſince the heat which emanates from the earth, decreaſes at each point as the ſpace increaſes, and this elevation of the ground alone ſuffices to explain this great difference of cold under the ſame latitude.

On this point there remains only one intereſting queſtion. Men, animals, and plants, may, for ſome time, ſupport the rigour of this cold, which is 60 degrees below the freezing point; but could they alike ſupport a heat which ſhould be 60 degrees above it? To this we anſwer, yes, provided we knew as well how to guard againſt the heat as we do to ſhelter ourſelves from the cold; and if the air could, during the remainder of the year, refreſh the earth, in the ſame manner as the emanation of the heat of the globe warm, the air in cold countries. We know of plants, inſects, and fiſh, which live and grow in baths of conſiderable heat; there are, therefore, ſpecies in living nature, which can ſupport this degree of heat; and as the negroes are in the human race thoſe whom a ſtrong heat the leaſt incommodes, might we not conclude, according to this hypotheſis, that earth has continued to decline from its original heat, and that the race of negroes are more ancient than that of white people.

GENERAL VIEWS OF NATURE.

FIRST VIEW.

NATURE is that ſyſtem of laws eſtabliſhed by the Creator for regulating the exiſtence of bodies and the ſucceſſion of beings. Nature is therefore not a body, for if it were ſo it would comprehend every thing; neither is it a being, for in that caſe it would neceſſarily be God. We muſt rather conſider Nature as an immenſe living power, which is in ſubordination to the Supreme Being, and by his command animates the univerſe, and whoſe actions are dependent on, and continued by, his concurrence or conſent. This power is that part of the Divine power which is manifeſted to mankind; it is the cauſe and effect, the mode and ſubſtance, the deſign and execution. Extremely different from all human art, whoſe productions are inanimate, Nature is herſelf a work perpetually alive, an active and unceaſing operator, who knows how to make uſe of every material, and though always employed on the ſame invariable plan, her power, inſtead of ſuffering diminution, is perfectly inexhauſtible: time, ſpace, and matter, are her means; the univerſe her object; and motion and life her end.

Every object in the univerſe are the effects of this power. Thoſe ſprings which ſhe makes uſe of are active forces which time and ſpace can only limit but never deſtroy; forces which unite, balance, and oppoſe, but incapable of annihilating each other. Some penetrate and connect bodies, others heat and animate them. It is principally by attraction and impulſion that this power acts upon brute matters, while heat and organic molecules are her chief active agents, which ſhe employs in the formation and expanſion of organized beings. Aided by ſuch inſtruments, how can the operations of Nature be limited? She only wants the additional power to create and annihilate to become omnipotent. But theſe two extremes the Almighty has reſerved to himſelf alone: the power of creating and annihilating are his peculiar attributes; that of changing, deſtroying, unfolding, renewing, and producing, are the only privileges he has conferred on this or any other agent. Nature, the miniſter of his *irrevocable* commands, the depoſitary of his immutable decrees, never deviates from the laws he has preſcribed to her; ſhe never changes any part of his original plan, but in all her operations ſhe exhibits the will and deſign of the eternal Lord of the univerſe. This grand deſign, this unalterable impreſſion of all exiſtence, is the model upon which ſhe invariably acts; a model which all the features are ſo ſtrongly impreſſed that they can never be effaced; a model which the infinite number of copies, inſtead of impairing, only ſerve to renew.

Therefore we may affirm that every thing has been created, but nothing annihilated; Nature acts between the two without ever reaching either the one or other extreme. It is in ſome points of this vaſt ſpace, which ſhe has filled and traverſed from the beginning of ages, that we muſt endeavour to lay hold of her to bring her into view.

What an infinity of objects, comprehending an infinity of matter, which would have been created in vain, had it not been divided into portions, ſeparated from each other by almoſt inconceivable ſpaces. Myriads of luminous globes, placed at immenſe diſtances, are the baſes which ſupport the fabric of the univerſe, and millions of opaque globes, which circulate round them, conſtitute the moving order of its architecture. By two primitive forces, each of which are in continual action, theſe maſſes are revolved and carried thro' the immenſity of ſpace; and their combined efforts produce the zones of the celeſtial ſpheres, and in the midſt of vacuity eſtabliſh fixed ſtations, and regular routes and orbits. From motion proceeds the equilibrium of worlds, and the repoſe of the univerſe. The firſt of theſe forces is equally divided, but the ſecond is ſeparated in unequal proportions. Every atom of matter contains the ſame degree of attractive force, while every individual globe has a different quantity of impulſive force aſſigned to each. Of the ſtars, ſome are fixed and others wandering; ſome globes appear formed to attract, and others for impelling or being impelled. Some ſpheres have received a common impulſion in the ſame direction, and others a particular impulſion. Some ſtars are alone, and others are attended by ſatellites; ſome are luminous, and others opaque maſſes. There are planets whoſe different parts ſucceſſively enjoy a borrowed light, and there are comets which, after being loſt in the immenſity of ſpace for ſeveral ages, return to receive the influence of the ſolar heat. There are ſome ſuns which appear and diſappear as if they were alternately kindled and extinguiſhed; and there are others which merely ſhew themſelves and then are ſeen no more. Heaven abounds with great events, but which the human eye is ſcarcely able to perceive. A ſun which expires and annihilates a world, or ſyſtem of worlds, has no other effect upon the eyes of man than an *ignis-fatuus*, which gives a tranſitory blaze and then vaniſhes for ever. Man, confined to the terreſtrial atom on which he vegetates, conſiders this atom as a world, and looks upon other worlds as atoms.

This earth which we inhabit is ſcarcely diſtinguiſhable among the other globes, and perfectly inviſible to the diſtant ſpheres; it is at leaſt a million times ſmaller than the ſun by which it is illuminated, and even a thouſand times leſs than ſome of the planets which, by its influence, the ſun compels to circulate around him. Saturn, Jupiter, Mars, the Earth, Venus, Mercury, and the Sun, occupy that ſmall portion of the heavens which we term our Univerſe. Theſe planets, with their ſatellites, moving with amazing celerity in the ſame direction, and almoſt in the ſame plane, compoſe a wheel of an immenſe diameter, whoſe axis ſupports the whole weight, and which by the rapidity of its own rotation muſt inflame and diffuſe heat and light throughout the whole circumference. As long as this regular motion continues (and which will be eternal, unleſs the Divine Mover exerts the ſame force to deſtroy as He thought neceſſary to create them) the ſun will burn and illuminate all the ſpheres of this univerſe with his ſplendor; and as, in a ſyſtem where the whole of the bodies mutually attract each other, nothing can be loſt, or removed without being returned, the quantity of matter muſt always remain the ſame; this great ſource of light and life can never be extinguiſhed or exhauſted, for the other ſuns, which alſo continually dart forth their fires, conſtantly reſtore to our ſun as much light as they take from him. Comets are more numerous than the planets, and like them depend on the power of the ſun; they alſo preſs on the common focus, and by augmenting the weight increaſe the inflammation. They may alſo be ſaid to form a part of our univerſe, for, like the planets, they are ſubject to the attraction of the ſun. But in their projectile and impelled motions they have nothing in common either with each other or with the planets. Every one of them circulates in a different plane, and they each deſcribe orbits in different periods of time; for ſome perform their revolutions in a few years, while others require ſeveral centuries. The ſun, juſt moving round his own centre, remains, in other reſpects, properly at reſt in the midſt, and, at the ſame time, ſerves as a torch, a focus, and an axis, to all and every part of this wonderful machine.

That the ſun continues immoveable, and regulates the motions of the other globes, is to be aſcribed to his magnitude alone. The force of attraction being in proportion to the maſs of matter; as the ſun is ſo conſiderably larger than any of the comets, and contains above a thouſand times more matter than the moſt extenſive planet, they can neither derange him nor diminiſh his influence, which extending to immenſe diſtances keeps the whole within the bounds of his power, and thus at particular periods recalls thoſe which have ſtretched fartheſt into the regions of ſpace. Some of theſe, on being brought back, approach ſo near the ſun, that after having cooled for ages they undergo an inconceivable degree of heat. From experiencing theſe alternate extremes of heat and cold, they are ſubject to ſingular viciſſitudes, as well as from the inequalities of their motions, which at ſome times are moſt amazingly rapid, and at others ſo infinitely ſlow as to be ſcarcely perceptible. In compariſon with the planets the comets may be conſidered as worlds in diſorder, for to them the orbits of the planets are regular, their movements equal, their temperature always the ſame; they appear to be places of reſt, where, every thing being permanent, Nature has the power of eſtabliſhing an uniform plan of operation, and ſucceſſively to mature her various productions. Among the planets the Earth, which we inhabit, ſeems to poſſeſs peculiar advantages; from being leſs diſtant from the ſun than Saturn, Jupiter, and Mars, it does not experience that exceſs of cold; nor is it ſo ſcorched as Venus and Mercury, which appear to revolve in an orbit too near the body of that luminary. Beſides, what a peculiar magnificence from Nature does the earth enjoy? A pure light, gradually extending from eaſt to weſt, alternately gilds both hemiſpheres of this globe; which is alſo ſurrounded with a pure tranſparent element. By a mild and fertile heat all the germs of exiſtence are animated and unfolded, and they are nouriſhed and ſupported by a plentiful ſupply of excellent waters. Conſiderable eminences diſperſed over the ſurface of the land, not only check, but collect the moiſt vapours which float in the air, and give riſe to perpetual mountains. Immenſe cavities evidently formed for the reception of thoſe waters, ſeparate iſlands, and continents. The ſea in extent is equal to that of the land: nor is this a cold and barren element, but a new empire, no leſs rich and no leſs furniſhed with inhabitants. By the finger of the Almighty are the limits of the waters marked out. If the ſea encroaches on the weſtern ſhores, it retreats from thoſe of the eaſt. This great maſs of water, though inactive of itſelf, is agitated, and put in motion by the influence of the celeſtial bodies, and from which ariſes its regular and conſtant flux and reflux; it riſes and falls with the courſe of the moon, and is always at the higheſt when the action of the ſun and moon concurs, and it is from theſe cauſes uniting at the time of the equinoxes, that the tides are then higher than at any other time; and this is certainly the ſtrongeſt mark of the connection of this globe with the heavens. Theſe general and conſtant motions are the cauſe of many variable and particular circumſtances; it is by thoſe that the tranſportations of the earth is occaſioned, which falling in the form of ſediment, produces mountains at the bottom of the ſea, ſimilar to thoſe which are on the ſurface of the land; they alſo give riſe to currents, which following the direction of theſe chains of mountains, beſtow on them a figure, whoſe angles correſpond, and maintaining a courſe in the midſt of the waves as waters run upon land, they may be conſidered, in fact, as ſea-rivers.

The Air being lighter and more fluid than water, is ſubject to the influence of a greater number of powers. It is conſtantly agitated by the effects of the ſun and moon, by the immediate action of the ſea, and by the rarefaction and condenſation of heat and cold. The winds are, as it may be ſaid, its currents; they force and collect the clouds, they give riſe to meteors, and tranſport the moiſt vapours of the ocean to the ſurfaces of iſlands and continents; from them proceed ſtorms, and they diffuſe and diſtribute the fertile dews and rains over the land; they interfere with the regular motions of the ſea, agitate the waters, ſometimes ſtop, and at others precipitate the currents,

rents, elevate the waves, and excite dreadful ſtorms and tempeſts. Forced by them the troubled ocean riſes towards the heavens, and with a tremendous noiſe and violence, ruſhes againſt thoſe immoveable barriers, which it can neither deſtroy nor ſurmount.

The Earth being elevated above the level of the ſea, is thus defended againſt its eruptions. Its ſurface is beautifully enamelled with various flowers, and a conſtant renewing verdure; it is inhabited by numberleſs ſpecies of inhabitants, and where man, placed to aſſiſt the intentions of Nature, preſides over every other being, finds a place of perfect repoſe, and a delightful habitation. He alone is endowed with knowledge, and dignified with the faculty of admiration; the Almighty has rendered him capable of diſtinguiſhing the wonders of the univerſe, and a witneſs of his increaſing miracles. Animated by a ray of divinity, he participates the myſteries of the Deity. It is by this ray that he is enabled to think and reflect, and that he perceives and underſtands the wonderful works of his Creator.

The external throne of the Divine magnificence is Nature; while man, by contemplating her, advances by degrees to the internal throne of the Almighty. He is formed to adore his Creator, and to have dominion over every other creature ; he is the vaſſal of heaven, and the lord of the earth ; by him this nether globe is peopled, ennobled, and enriched ; he eſtabliſhes order, ſubordination, and harmony among living beings, and even to Nature herſelf he gives poliſh, extenſion, cultivation, and embelliſhment ; for he cuts down the thiſtle and bramble, and, by his care, multiplies the vine and the roſe. In thoſe dreary deſarts where man has not inhabited, we find them over-run with thorns and briars ; the trees deformed, broken, and corrupted, and the ſeeds which ought to renew and embelliſh the ſcene, are choaked by ſurrounding rubbiſh, and reduced to ſterility. Nature, who, in other ſituations, we find adorned with the ſplendour of youth, has here the appearance of old age and decrepitude. Here the earth, overloaded with the ſpoils of its productions, inſtead of preſenting a ſcene of beautiful verdure, exhibits only a rude maſs of coarſe herbage, and trees loaded with paraſitical plants, as lickens, agaries, and other impure and corrupted fruits ; the low grounds are covered with putrid and ſtagnating waters ; theſe miry lands being neither ſolid nor fluid, are not only impaſſable, but are entirely uſeleſs to the inhabitants of both land and water; and the marſhes abounding with ſtinking aquatic plants, ſerve only to nouriſh venomous inſects, and to harbour infectious animals. There is, beſides, between the putrid marſhes of the low grounds, and the decayed foreſts of the high parts of the country, a ſpecies of lands, or ſavannas, but which are very different to our meadows; for in them there is an abundance of noxious herbs which ſpring up, and check the growth of the uſeful kinds: inſtead of that delicate enamelled turf, which may be conſidered as the down of the earth, they are covered over with coarſe vegetables and hard prickly plants, which are ſo interwoven, that they appear to have more connection with each other, than with the ſoil; and by a conſtant and ſucceſſive ſpringing up, at length form a kind of rough mat ſeveral feet thick. In theſe uncultivated and deſolate regions, there is no road, no communication, and no veſtige of intelligence. Man, when ſeeking to deſtroy the wild beaſts, is under the neceſſity of following their tracks, and is obliged to be on the conſtant watch, leſt he ſhould become a victim to their ſavage fury; alarmed and terrified by their frequent roarings, and even awed by the profound ſilence of thoſe dreary ſolitudes, he ſhrinks back and exclaims;

" Uncultivated Nature is hideous and un-
" flouriſhing ; it is I alone who can render
" her agreeable and vivacious. Let us drain the
" marſhes, and give animation to the waters,
" by converting them into brooks and canals ;
" let us make uſe of that active and devouring
" element, whoſe power we have diſcovered ;
" let us apply fire to this burthenſome load of
" vegetables, and to thoſe decaying foreſts
" which are already half deſtroyed ; let us
" complete the work by deſtroying with iron
" what cannot be diſſipated by fire ; and then
" inſtead of coarſe reeds and water-lillies, from
" which the toad is ſaid to extract his poiſon,
" we ſhall ſoon behold the ranunculus, truffles,
" and other mild and ſalutary herbs ſpring up ;
" that land, which was formerly impaſſable,
" will become a flouriſhing paſture for flocks
" of cattle, where they will find plenty of
" food, a never-failing ſupply, and where, by
" the excellence of their ſuſtenance, they will
" increaſe and multiply, and thus reward us
" for our labours and the protection we have
" given them. Let us ſtill go farther, and
" ſubject the ox to the yoke, let his ſtrength
" and weight of body be employed to plough
" the ground, which acquires freſh vigour
" from culture. Thus will the operations of
Nature,

" Nature be aſſiſted, and acquire double " ſtrength and ſplendor from the ſkill and in- " duſtry of man."

How beautiful is cultivated Nature! How beautiful does ſhe appear when decorated by the hand of man! He is himſelf her chief ornament, her nobleſt production, and by multiplying his own ſpecies he increaſes the moſt precious of her works. She even ſeems to multiply in proportion with his attention, for by his art he developes all ſhe has concealed in her boſom. What a ſource of unknown treaſures has been brought to light! flowers, fruits, and grains, matured to perfection, and multiplied to infinity; the uſual ſpecies of animals tranſported, propagated, and increaſed, without number; the noxious and deſtructive kinds diminiſhed and driven from the habitations of men; gold, and iron, a more uſeful metal, extracted from the bowels of the earth; torrents reſtrained, rivers directed in their courſes and confined within their banks, and even the ocean itſelf ſubdued, inveſtigated and traverſed from one hemiſphere to the other; the earth rendered active, fertile, and acceſſible, in every part; the vallies and plains changed into blooming meadows, rich paſtures, and cultivated fields; the hills ſurrounded with vines and fruits, and their ſummits crowned with uſeful trees; the deſarts converted into populous cities, whoſe inhabitants ſpread from its centre to its utmoſt extremities; roads and communications opened, eſtabliſhed, and frequented, as ſo many proofs of the union and ſtrength of ſociety. There are alſo a thouſand other monuments of power and *glory*, which clearly demonſtrate that man is the lord of the earth; that he has changed and improved its ſurfaces; and that from the earlieſt periods of time he alone has divided the empire of the world between him and Nature.

It is by the right of conqueſt, however, that he reigns, for he rather enjoys than poſſeſſes, and it is by conſtant and perpetual activity and vigilance that he preſerves his advantage, for if thoſe are neglected every thing languiſhes, changes, and returns to the abſolute dominion of Nature. She reſumes her power, deſtroys the operations of man; envelopes with moſs and duſt his moſt pompous monuments, and in the progreſs of time entirely effaces them, leaving man to regret having loſt by his negligence what his anceſtors had acquired by their induſtry. Thoſe periods in which man loſes his empire, thoſe ages in which every thing valuable periſhes, commence with war, and are completed by famine and depopulation. Although the ſtrength of man depends ſolely upon the union of numbers, and his happineſs is derived from peace, he is, nevertheleſs, ſo regardleſs of his own comforts as to take up arms and to fight, which are never-failing ſources of ruin and miſery. Incited by inſatiable avarice, or blind ambition, which is ſtill more inſatiable, he becomes callous to the feelings of humanity; regardleſs of his own welfare, his whole thoughts turn upon the deſtruction of his own ſpecies, which he ſoon accompliſhes. The days of blood and carnage over, and the intoxicating fumes of glory diſpelled, he beholds, with a melancholy eye, the earth deſolated, the arts buried, nations diſperſed, an enfeebled people, the ruins of his own happineſs, and the loſs of his real power.

Omnipotent God! by whoſe preſence Nature is ſupported, and harmony among the laws of the univerſe maintained; who ſeeſt from thy immoveable throne in the Empirean all the celeſtial ſpheres rolling under thy feet without deviation or diſorder; who, from the boſom of repoſe, every inſtant reneweſt their vaſt movements, and who alone governs in profound peace an infinite number of heavens and of earths, reſtore, reſtore tranquillity to a troubled world! Let the earth be ſilent! Let the preſumptuous tumults of war and diſcord be diſpelled by the ſound of thy voice! Merciful God! author of all beings, whoſe paternal regards extend to every created object; but man is thy principal favourite; thou haſt illuminated his mind with a ray of thy immortal light, penetrate alſo his heart with a ſhaft of thy love; thy divine ſentiment, when univerſally diffuſed, will unite the moſt hoſtile ſpirits; man will no longer be apprehenſive of the aſpect of man, nor will his hand any longer continue to be armed with murdering ſteel; the devouring flames of war will no longer ſtop the ſources of generations; the human ſpecies, which are now weakened, mutilated, and prematurely mowed down thereby, will germinate anew, and multiply without number. Nature, groaning under the preſſure of calamity, ſterile and abandoned, with additional vigour will ſoon reſume her former fecundity; and we, beneficent God, ſhall aid, cultivate, and inceſſantly contemplate her operations, that we, at every moment, may be enabled to offer thee a freſh tribute of gratitude and admiration.

SECOND VIEW.

Of whatever kind, or however numerous, individuals are of no eſtimation in the univerſe; it is ſpecies alone that are exiſtences in Nature, for they are as ancient and permanent as herſelf. To have a clear and diſtinct idea of this ſubject we muſt not conſider a ſpecies as a collection or ſucceſſion of ſimilar individuals, but as a whole, independent of number or time, always active, and always the ſame; a whole which was conſidered but as one in the works of the creation, and therefore conſtitutes only an unit in Nature. Of theſe units the human ſpecies is to be placed in the firſt rank; all the others, from the elephant to the mite, from the cedar to the hyſſop, belong to the ſecond and third orders. Notwithſtanding they are different in form, ſubſtance, and even life, yet each ſuſtains its appointed deſtination, and ſubſiſts independent of others, while the whole, in a general view, repreſents animated Nature, who has hitherto ſupported, and will continue to ſupport, herſelf in the ſame manner as ſhe is ſeen at preſent. Her duration is not to be eſtimated by a day, a year, an age, nor any given period of time, for time itſelf relates only to individuals, to beings whoſe exiſtence is limited. It is not ſo with reſpect to ſpecies, for their exiſtence is conſtant; their permanence produces duration, and their differences give riſe to number. It is in this light we muſt conſider ſpecies, and give to each an equal right to the indulgence and ſupport of Nature; for ſo ſhe has certainly conſidered them, by beſtowing on each the means of ſubſiſtence, and of exiſting as long as herſelf.

Let us now conſider the ſpecies as having changed places with the individual. In our preceding obſervations we have ſeen the relation Nature holds in reſpect to man; let us then now take a view in what light ſhe would appear to a being who repreſented the whole human ſpecies. We perceive that in the ſpring the fields renew their verdure, the buds and flowers expand, the bees revive from their ſtate of torpor, the ſwallows, &c. return to our climates, the nightingale chants her ſong of love, the lamb friſks, and the bull lows with deſire, and all animated creatures are eager to unite and multiply their ſpecies; and we can then have no ideas but thoſe of reproduction and the increaſe of life. But when the dark ſeaſon of cold and froſt approaches, theſe ſame beings become indifferent to and avoid each other; many of the feathered race deſert our clime, and the inhabitants of the waters loſe their freedom under maſſy congelations of ice; various animals dig retreats for themſelves in the ground, where they fall into a ſtate of torpor; the earth becomes hard, the plants wither, and the trees deprived of their foliage are covered with froſt and ſnow; and every object excites the idea of languor and annihilation. Theſe appearances, however, of renovation and deſtruction, or rather images of life and death, although they ſeem general, are only individual and particular. Man, as an individual, concludes in this manner, but the being whom we have ſuppoſed as a repreſentative of the ſpecies, thinks and judges in a manner more exalted and general; in that conſtant ſucceſſion of deſtruction and renovation, and in thoſe various viciſſitudes, he perceives only permanence and duration. The different ſeaſons in one year appear to him the ſame as thoſe of the preceding, the ſame as thoſe of millions of ages. The animal which may be the thouſandth in the order of generation is the ſame to him as the firſt. In a word, if man had no period to his exiſtence, and if all the beings by which he is ſurrounded exiſted in the ſame manner as they do at preſent, the idea of time would vaniſh, and the individual would in fact become the ſpecies.

Let us then conſider Nature for a few moments under this new aſpect. Man certainly comes into the world enveloped in darkneſs. His mind is equally naked with his body; he is born without knowledge and without defence, and brings nothing with him but paſſive qualities. The impreſſions of objects he is under the neceſſity of receiving on his organs; even the light ſhines long on his eyes before he is able to recognize it. To Nature he is, at firſt, indebted for every thing, without making her any return. No ſooner, however, does his ſenſes acquire ſtrength and activity, and he can compare his ſenſations, than he reflects upon the univerſe; he forms ideas, which he retains, extends, and combines. Man, after receiving inſtruction, is no longer a ſimple individual, for he then, in a great meaſure, repreſents the whole human ſpecies. He receives from his parents the knowledge which had been tranſmitted to them from their forefathers; and thus, by the divine arts of writing and printing, the preſent age, in ſome ſort, becomes identified with thoſe that are paſt. This accumulation of the experience of many centuries in one man, almoſt extends the limits of his being to infinity. He is born no more than a ſimple individual, like other animals, capable only of attending to preſent ſenſations; but afterwards he becomes nearly the being we ſuppoſed to repreſent the whole ſpecies, he reads what has paſt, ſees the preſent, and judges of the future; and in the torrent of time, which carries off and abſorbs all the individuals of the univerſe, he perceives that the ſpecies are permanent, and Nature invariable. As the relations of objects are always the ſame, to him the order of time appears to be nothing; he conſiders the laws of renovation as only counterbalancing thoſe of permanency. An uninterrupted ſucceſſion of ſimilar beings, is, in effect, only equivalent to the perpetual exiſtence of one of them.

What purpoſes then are ſerved by this immenſe train of generations, this profuſion of germs, many thouſands of which are aborttive for one that is brought into life? Does not this perpetual propagation of beings, which are alternately deſtroyed and renewed, uniformly exhibit the ſame ſcene, and occupy the ſame proportion of Nature. From what cauſe proceeds all theſe changes of life and death, theſe laws of growth and decay, all thoſe individual viciſſitudes, and reiterated repreſentations of the ſame identical thing? They certainly ariſe from the very eſſence of Nature, and depend on the firſt eſtabliſhment of the univerſal machine; the whole of which is fixed and ſtable, but each of its parts being endowed with the power of motion, the general movements of the celeſtial bodies have produced the particular ones of this terreſtrial globe. The penetrating forces by which theſe immenſe bodies are animated, and by which they act reciprocally upon each other at a diſtance, at the ſame time animate every particle of matter; and this ſtrong propenſity, which every part has towards each other, is the firſt bond of beings, the ground of conſiſtence and permanency in Nature, and the ſupport of harmony in the univerſe. From theſe great combinations the ſmaller relations are derived. The earth moving on its own axis having ſeparated the portions of duration into day and night; all its animated inhabitants have their ſtated periods of light and darkneſs, of their times of waking and ſleeping. The action of the ſenſes, and the motions of the members which form a great part of the animal economy, are related to this firſt combination; for in a world where perpetual darkneſs reigned, would there be ſenſes alive to the enjoyment of light?

As the inclination of the axis of the earth, in its annual courſe round the ſun, produces conſiderable variations of heat and cold, which we call Seaſons, all its vegetables have alſo, either wholly or partially, their ſeaſons of life and death. The fall of the leaves, and the decay of fruits, the withering of herbs and the deſtruction of inſects, depend entirely on this ſecond combination. In thoſe climates, where there is not this variation, by the inclination not being ſo material, the life of the vegetable is not ſuſpended, and every inſect completes the ſtated period of its exiſtence. Where the four ſeaſons, in fact, make but one, as under the line, the ſurface of the earth is conſtantly covered with flowers, the trees have a perpetual foliage, and Nature ſeems to enjoy a continual ſpring.

Both in animals and plants, their particular conſtitution is relative to the general temperature of the earth, and which temperature depends upon its ſituation and diſtance from the ſun. If they were removed to a greater diſtance, neither our animals, nor plants, could live or vegetate; the water, ſap, blood, and all their liquors, would loſe their fluidity ; and if they were more near they would vaniſh and diſſipate in vapour. Ice and fire are the elements of death, and temperate heat the firſt ſupport of life. The living particles ſo generally diffuſed through all organized bodies are related, not only by their activity but number, to the particles of light which ſtrike and penetrate almoſt all matter with their heat ; for in every place where the ſun can heat the earth, with its rays, the ſurface will be covered with verdure, and peopled with animals; even ice is no ſooner diſſolved into water than it ſwarms with inhabitants. Water, indeed, is apparently more fertile than the earth ; from heat it receives motion and life. In one ſeaſon the ſea produces more animals than the earth ſuſtains, but its productions of vegetables is infinitely leſs. And it is from this circumſtance, namely, the inhabitants of the ocean not having a ſufficient and permanent ſupply of vegetables, that they feel a neceſſity for feeding upon each other ; and it is to this neceſſity that their immenſe multiplication may be referred.

As in the beginning every ſpecies was created, the firſt individual of each has ſerved for a model to their deſcendants,

ants. The body of each animal or vegetable is a mould, to which are aſſimilated indifferently the organic particles of all animals or vegetables which have been deſtroyed by death, or conſumed by time. The brute particles, of which part of their compoſition was formed, returned to the common maſs of inanimate matter; but the organic particles, whoſe exiſtence is permanent, are again reſumed by organized bodies: they are extracted at firſt from the earth by vegetables, and then abſorbed by animals who feed thereon; and thus ſerve for the ſupport, growth, and expanſion of both. By this conſtant and perpetual circulation from body to body, they ſerve to animate all organized beings. Theſe living ſubſtances in quantity are always the ſame, and differ only in form and appearance. In fertile ages, and when population is the greateſt, the whole ſurface of the earth ſeems to be covered with men, domeſtic animals, and uſeful plants. But in the times of famine and depopulation, the ferocious animals, poiſonous inſects, paraſitical plants, and uſeleſs herbs, reſume, in their turn, dominion over the earth. To man theſe changes are material, but to Nature they are perfectly indifferent. The ſilk worm, ſo ineſtimable to the former, is to the latter only a caterpillar of the mulberry tree. Tho' this caterpillar, which ſo materially aſſiſts in the ſupply of our luxuries, ſhould diſappear; though the plants, from which our domeſtic animals procure their nouriſhment, ſhould be devoured by other caterpillars; though ſtill others ſhould deſtroy the ſubſtance of our corn before the harveſt; in ſhort, though man and the larger animals ſhould be ſtarved by the inferior tribes, Nature would not be leſs abundant nor leſs alive; ſhe never protects one at the expence of another, but equally ſupports the whole. As to individuals ſhe is regardleſs of number, conſidering them only as ſucceſſive images of the ſame impreſſion; as paſſing ſhadows of which the ſpecies is the ſubſtance.

In earth, air, and water, then, there exiſts a certain quantity of organic matter which cannot be deſtroyed, but which is conſtantly aſſimilated in a certain number of moulds, that are perpetually undergoing deſtruction and renewal; and theſe moulds, or rather individuals, though varying in number in every ſpecies, are nevertheleſs always the ſame, that is proportioned to the quantity of living matter; and this appears to be certainly the caſe, for if there were any redundance of this matter, or if it was not at all times fully occupied by the individuals of the ſpecies which exiſt, it would, moſt undoubtedly, form itſelf into new ſpecies, for being alive it would not remain without action ; and once uniting with brute matter is ſufficient to form organized bodies ; and it is by this conſtant combination, and invariable proportion, that Nature preſerves her form and conſiſtence.

The laws of Nature, both with reſpect to the number of ſpecies and of their ſupport and equilibrium, being fixed and conſtant, ſhe would invariably have the ſame appearance, and be in all climes abſolutely the ſame, if her complexion did not ſo completely vary in almoſt every individual form. The figure of each ſpecies is an impreſſion, in which the principal characters are ſo ſtrongly engraven as never to be effaced ; but the acceſſory parts and ſhades are ſo greatly varied that no two individuals have a perfect reſemblance to each other ; and in all ſpecies there are a number of varieties. The human ſpecies, which has ſuch ſuperior pretenſions, varies from white to black, from ſmall to great, &c. The Laplander, the Patagonian, the Hottentot, the European, the American, and the Negro, though the offſpring of the ſame parents, have by no means the reſemblance of brothers.

It is evident, therefore, that all ſpecies are ſubject to individual differences, but each of them do not equally poſſeſs the conſtant varieties which are perpetuated through ſucceſſive generations; the more dignified the ſpecies the leſs changeable is its figure, and the leſs are the varieties of it. The multiplication of animals being inverſely in proportion to their magnitude, as the poſſibility of variation muſt be in exact proportion to the numbers they produce, there conſequently muſt be more varieties among the ſmall than the large animals; and alſo, for the ſame reaſon, there will be a greater number of ſpecies which ſeem to approach each other, for the unity of the ſpecies in the large animals is more fixed, and the nature of their ſeparation more extended. What a number of various and ſimilar ſpecies ſurround thoſe of the ſquirrel, the rat, and other ſmall quadrupeds, while the maſſy elephant ſtands alone, without a compeer, and at the head of the whole.

The brute matter, of which the body of the earth is principally compoſed, is a ſubſtance that has not undergone many alterations; although the whole, by the hand of Nature, has more than once been diſturbed and put in motion.

tion. The globe of the earth has been penetrated by fire, and afterwards covered and diſordered by water. The ſand, which occupies the interior parts of the earth, is a vitrified matter; and the layers of clay, by which its ſurface is covered, are nothing but the ſame ſand having been decompoſed by the operation of the waters. Granate, free-ſtone, flint, nay, and even all metals, are all compoſed of this ſame vitrified matter, whoſe particles have been condenſed or ſeparated, according to the laws of their affinity. Theſe ſubſtances are totally deſtitute of animation; they exiſt, and will continue to do ſo, independent of animals and vegetables. There are, however, many other ſubſtances, which, although they have the appearance of being equally inanimate, originate from organized bodies; and of this deſcription are marble, lime-ſtone, chalk, and marl; they being compoſed of the fragments of ſhells, and of thoſe ſmall animals which, by transforming the water of the ſea into ſtone, produce coral, and all the madrepores, whoſe varieties are numberleſs, and quantity almoſt immenſe. Pit-coal, turf, and many other ſubſtances found in the upper ſtrata, are alſo of this nature, they being only the reſidue of vegetables which have been more or leſs corrupted or conſumed.

Beſides theſe, there are other ſubſtances which have been produced by the ſecond action of fire upon original matters; theſe are but few in number, and conſiſt of ſuch as pumice-ſtones, ſulphur, the ſcoria of iron, aſbeſtos, and lava. To one or other of theſe three great combinations may be referred all the relations of brute matter, and all the ſubſtances of the mineral kingdom.

The laws of affinity, by which the various particles of theſe different ſubſtances ſeparate from each other, in order to unite among themſelves, and form homogeneous maſſes, are perfectly ſimilar with that general law by which the celeſtial bodies act upon each other; in both caſes their exertions are the ſame. Globules of water, of ſand, or of metal, have the ſame influence, and act upon each other as the earth acts upon the moon; and if the laws of affinity have hitherto been deemed as different from thoſe of gravity, it is becauſe the ſubject has been conſidered in a very confined point of view. The mutual action of celeſtial bodies is very little influenced by figure, their diſtance from each other being ſo very great, but the effect of figure is very conſiderable where they are not far aſunder. For inſtance, if the earth and moon, inſtead of ſpherical figures, were both ſhort cylinders, and exactly equal throughout in their diameters, their reciprocal action would be very little varied from what it is at preſent, becauſe the diſtances of all their parts from each other would be very little changed. But if theſe two globes were cylinders of great extent, and approached near each other, the law of their reciprocal action would ſeem to be different, inaſmuch as the diſtances of their parts would be greatly varied; and from which, whenever figure becomes a principal in diſtance, the law will appear to vary, although in fact it is always the ſame.

The human intellect, guided by this principle, may advance one ſtep farther in penetrating into the operations of nature. The figure of the conſtituent particles of bodies ſtill remains unknown; we cannot entertain the ſmalleſt doubt that water, air, earth, metals, and all homogeneous particles, are compoſed of elementary particles, which are perfectly ſimilar, although we are ſtill ignorant of their figure. By the aid of calculation this at preſent unknown field of knowledge may be diſcloſed by poſterity, and the figure of the elementary bodies be aſcertained with tolerable preciſion. They may take the principle we have eſtabliſhed as the baſis of their enquiry;

namely, "That all matter is attracted in the "inverſe ratio of the ſquare of the diſtance; "and this law ſeems to admit of no variation "in particular attractions but what ariſes from "the figure of the conſtituent particles of each "ſubſtance, becauſe this figure enters as an "element or principle into the diſtance;" and having once diſcovered, by repeated experiments, the law of attraction in any particular ſubſtance, they may then, by the aid of calculation, be able to trace the figure of its conſtituent particles. To render this point more clear, let us ſuppoſe, that by placing mercury on a perfectly poliſhed ſurface, repeated experiments prove that this fluid metal is always attracted in the inverſe ratio of the cube of the diſtance; it will then become neceſſary to inveſtigate what figure gives this expreſſion; and this figure will certainly be that of the conſtituent particles of mercury. If it ſhould appear, by ſuch experiments, that the attraction of mercury was in the inverſe ratio of the ſquare of the diſtance, it would be clearly demonſtrated that its conſtituent particles were ſpherical, becauſe a ſphere is the only figure which obſerves this law, and at whatever diſtance globes are placed the law of their attraction is always the ſame.

Newton had ſome idea that chemical affinities (which are nothing more in fact than theſe particular attractions we have mentioned) were produced by the ſame kind of laws as thoſe of gravitation; but he does not appear to have perceived that all thoſe particular laws were merely ſimple modifications of the general one, and that their appearing to differ aroſe ſolely from the circumſtance of the figure of the atoms, which attract each other, having, when at ſmall diſtances, a greater influence upon the force of this law than the maſs of matter.

It is, notwithſtanding, upon this theory that the perfect knowledge of brute matter depends. The baſis of all matter is the ſame, and its form throughout would be perfectly ſimilar, if the figures of its conſtituent particles were not different; and thus it is that one homogeneous ſubſtance can differ only from another in proportion to the difference of their original particles. A body compoſed of ſpherical particles ought to be one half ſpecifically lighter than that whoſe particles are cubical, becauſe as the firſt only touch each other by their points they leave ſpaces between equal to what they occupy, whereas the cubical particles join without leaving the ſmalleſt interval, and muſt conſequently form a matter half as heavy again.

Although the figures are conſiderably varied, that variation is by no means ſo numerous as we might imagine, ſince Nature has fixed the limits of levity and gravity. Gold and air, with reſpect to denſity, are the two extremes, and therefore all the figures in Nature muſt be comprehended as coming between thoſe two; ſuch as would have produced heavier or lighter ſubſtances have been rejected.

In ſpeaking of figures, as employed by Nature, I do not mean to imply they muſt be neceſſarily, or are exactly, ſimilar to thoſe geometrical figures which we form in our imagination. We form laws by ſuppoſition, and then endeavour to render them ſimple by abſtraction. It is very poſſible that there are neither exact cubes nor perfect ſpheres in the univerſe; but as certainly nothing exiſts without form, and as from the variation of ſubſtances the figures of the elements are different, ſome of them moſt undoubtedly muſt approach to the ſphere, the cube, and all the other regular figures which we have conceived. The preciſe, abſolute, and abſtract, which our minds are ſo frequently induced to admit, cannot have any exiſtence, becauſe all objects are related, differ only by almoſt imperceptible ſhades, and are allied by proximation. It is by the ſame rule that when I ſpeak of one ſubſtance as being entirely full, becauſe compoſed of cubical particles, and another as being not more than half full, becauſe its parts are ſpherical, I mean only comparatively, and not that ſuch ſubſtances really exiſt; for experience has fully informed us, that in tranſparent bodies, ſuch as glaſs, which is both denſe and heavy, there is but a ſmall quantity of matter in proportion to the extent of the intervals; nay, as we have before obſerved, it might be demonſtrated that even gold, which is the moſt denſe ſpecies of matter, has more vacuities than ſubſtance.

To inveſtigate the powers of Nature is the object of rational mechanics, while actual mechanics is ſolely confined to a combination of particular powers, and conſequently the art of conſtructing machines. This art has at all times been ſecure of cultivation from neceſſity and convenience; and both ancients and moderns have equally excelled in it. But rational mechanics is a ſcience invented in our days, for from the days of Ariſtotle to thoſe of Deſcartes, even the philoſophers have reaſoned no better upon the nature of motion, but have uniformly miſtaken the effect for the cauſe. Impulſion was the only force with which they were acquainted, to which they attributed the effects of others, and referred to it all the phenomena of the univerſe. If this idea of theirs had been probable, or even poſſible, impulſion which they regarded as the ſole cauſe, muſt have been a general effect, which equally belonged to all matter, and which equally exerted itſelf in all places, and at all times; but every day demonſtrated the contrary to be the fact; for they muſt have perceived that this force had no exiſtence in bodies at reſt; that it had but a ſhort ſubſiſtence in projected bodies, being ſoon deſtroyed by reſiſtance; that a freſh impulſe was abſolutely neceſſary for its renewal, and that, conſequently, ſo far from being a general cauſe, it was only a particular effect produced by others more general.

It is, however, true, that we ought to conſider a general effect as a cauſe, for we cannot be acquainted with the real cauſe of this effect, becauſe all our knowledge is derived from compariſon; and as there is not any thing to which we can compare an effect, which is ſuppoſed general and equally belonging to every thing, we can know it only by the fact. According to this view, attraction, or gravity, being a general effect common to all matter, and clearly evinced by the fact, ought to be conſidered as a cauſe;

a cauſe; and to which all particular cauſes ſhould be referred, nay even that of impulſion, ſince it is leſs general and leſs conſtant; and the principal difficulty is to perceive how impulſion can be an effect of attraction; for if we reſt on the communication of motion by impulſe, we are then perſuaded that it can only be tranſmitted from one body to another by elaſticity, and that all the hypotheſes, which ſuppoſe a communication of motion in hard bodies, are mere ideal fancies, which do not exiſt in Nature. A perfectly hard or a perfectly elaſtic body is entirely imaginary, as neither of them really exiſt; for it is certain that nothing exiſts abſolutely or in extreme; and the idea of perfection muſt ſuppoſe one or the other.

It is certain that if there was no elaſticity in matter there would be no impulſive force; for inſtance, if we throw a ſtone, the motion it acquires is communicated by the elaſticity of the arm. When motion is communicated by one body in action encountering another at reſt, how can we poſſibly ſuppoſe it to be done than by compreſſing the ſpring of the elaſtic particles it contains, which almoſt immediately after recovering itſelf gives to the whole maſs an equal force to that which it received. How a perfectly hard body ſhould admit this force, or receive motion, is beyond comprehenſion; and the enquiry is unneceſſary, ſince no ſuch body exiſts; for, on the contrary, all bodies are endowed with elaſticity. The force of electricity is proved by experiments to be elaſtic, and to belong to matters in general; and therefore if no other elaſticity exiſted in the interior parts of bodies but that of this electrical matter, that would be ſufficient for the communication of motion; and, conſequently, to this great ſpring as a general effect, the particular cauſe of impulſion muſt be attributed.

A little reflection on the mechaniſm of elaſticity will convince us that its force depends on that of attraction. To have a ſtill more clear idea of this ſubject, let us ſuppoſe a ſpring of the moſt ſimple, ſuch as of a ſolid angle of iron, or of any other hard ſubſtance, and then ſee what will be the reſult of compreſſing it. By compreſſion we oblige the parts adjacent to the top of the angle to bend, or to ſeparate a little from each other; but the preſſure being removed they again approach as near as they had done before. Their adheſion, from which the coheſion of bodies reſults, is clearly an effect of their mutual attraction. Upon the ſpring being preſſed this adheſion is not deſtroyed, becauſe, although the particles are ſeparated, they are not removed beyond the ſphere of their mutual attraction; conſequently the moment the preſſure is taken away the force is renewed, the ſeparated parts draw near, and their ſpring is reſtored. But if the preſſure is too violent, they will, in that caſe, be removed beyond the ſphere of their attraction, and the ſpring will break, becauſe the compreſſing force will have been greater than that of coheſion, or that of mutual attraction, by which the particles are kept together. This proves that elaſticity can only exert itſelf in proportion to the coheſion of the particles of matter, that is, in proportion as they are united by the force of their mutual attraction; from which it reſults, that elaſticity in general, which alone can produce impulſion, and impulſion itſelf, are owing to the force of attraction, and are only particular effects which depend on that general one.

Notwithſtanding theſe ideas appear to be perfectly clear to me I do not expect to ſee them adopted. The people in general reaſon only from their ſenſations, and natural philoſophers determine from their prejudices; as, therefore, both theſe muſt be ſet aſide, very few will remain to form a proper judgment; but ſuch is the ſtate of Truth, ſhe is content with a few admirers, and is always loſt in a crowd ; ſhe is at all times auguſt and majeſtic, notwithſtanding which ſhe is frequently obſcured by fantaſtic opinions, and obliterated by fanciful chimeras. I, however, view and underſtand Nature in this manner, (and am almoſt induced to believe ſhe is ſtill more ſimple) the phenomena exhibited by brute matter is cauſed by a ſingle force, and from this force, combined with that of heat, originate thoſe living particles which gave riſe to, and ſupport all, the various effects of organized bodies.

FINIS.